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CONTENTS

	Page	Russian Page
EFFECT OF THE VESELOVSKOYE RESERVOIR ON SOILS OF ADJACENT AREAS, by S. A. Vladychenskiy	109	1
THEORY OF THE CONDENSATION OF ATMOSPHERIC MOISTURE IN SOIL, by V. I. Tochilov	114	7
MICROELEMENTS IN SEVERAL SOILS AND SOIL-FORMING PARENT MATERIALS OF KAZAKHSTAN, by V. V. Dobrovol'skiy	120	15
DARK CHESTNUT CARBONATE SOLONETZ-LIKE SOILS OF NORTHERN KAZAKHSTAN, by A. M. Durasov	128	24
THE IMPORTANCE OF THE CRYPTO-GEOLOGICAL STRUCTURE OF CENTRAL ASIAN ALLUVIAL PLAINS FOR RECLAMATION PURPOSES, by A. A. Aleksin	135	32
EFFECTS OF DRAINAGE ON THE FOREST-GROWING PROPERTIES OF PEAT-HUMUS SOILS, by A. Ya. Orlov and A. A. Izvekov	141	40
ROLE OF SOIL-ADSORBED AMMONIUM IN THE NITROGEN NUTRITION OF PLANTS, by A. Ye. Vozbutskaya	149	50

METHODS

	Page	Russian Page
RESPIRATION OF SOIL AND COMPOSITION OF SOIL AIR ON DRAINED PEAT-BOG SOILS, by B. N. Makarov	154	56
WATER PERMEABILITY OF CERTAIN SOD-PODZOLIC SOILS, by V. A. Chernyshov	161	63
AN ERRONEOUS THEORY OF SOIL MOISTURE MOVEMENT, by S. V. Nerpin and M. K. Mel'nikova	170	71
WIND EROSION OF COARSE-TEXTURED SOILS IN PAVLODARSKAYA OBLAST', by L. F. Smirnova	174	75
SOIL EROSION AND ITS EFFECTS ON YIELD IN AREAS OF THE VOLGA UPLAND, by A. V. Tikhonov	180	80
INVESTIGATION OF ORGANIC MATTER IN PODZOLIC COHESIVE SANDY SOILS, by A. Muserovich, S. Brogovski, and T. Skorupska	188	89

	Page	Russian Page
TO INTENSIFY THE DEVELOPMENT OF RATIONAL METHODS FOR FIELD AND LABORATORY SOIL INVESTIGATIONS, an Editorial	189	90
THE USE OF SODIUM PYROPHOSPHATE FOR ISOLATING FREE HUMIC SUBSTANCES AND THEIR ORGANIC-MINERAL COMPOUNDS FROM THE SOIL, by L. N. Aleksandrova	190	90
QUICK AND SIMPLE ELECTROMETRIC METHOD FOR DETERMINING SULFATE IN SALINIZED SOILS, by D. Ye. Golkin, L. N. Lozanova, I. B. Pinayeva, and L. V. Aleksandrova	198	97
A RAPID AND ACCURATE METHOD OF DETERMINING THE ADSORPTION CAPACITY OF CALCAREOUS SOILS, by K. Ya. Kozhevnikov	201	100
A PHOTOMETRIC METHOD OF DETERMINING TOTAL PHOSPHORUS IN SOIL, by M. L. Tsap and G. L. Linnikova	203	102
A RAPID METHOD OF DETERMINING ADSORBED SODIUM AND POTASSIUM IN CALCAREOUS SOILS, by K. Sh. Shatemirov	208	107

REVIEW

	Page	Russian Page
THE TEACHING OF SOIL SCIENCE IN FORESTRY COLLEGES AND THE TEXTBOOK OF PROFESSOR A. A. RODE, by S. V. Zonn, V. N. Smirnov, and A. A. Molchanov	211	110
BIBLIOGRAPHY	214	113

EFFECT OF THE VESELOVSKOYE RESERVOIR ON SOILS OF ADJACENT AREAS

S. A. VLADYCHENSKIY, Moscow State University

This article presents results of investigations made in the summer of 1958 by the expedition of the Department of Physics and Soil Melioration, Moscow State University, at the Veselovskoye Reservoir (Rostovskaya Oblast') as part of the research by the department on the study of the effect of reservoirs on soils.[1]

The Veselovskoye Reservoir is located in the Manych River Valley between the Veselyy Farmstead and the Proletarskaya Station. The reservoir is about 100 kilometers long with a capacity of 900 million cubic meters. The reservoir was constructed in 1933. Following the Great Fatherland War the dam, which had been destroyed, was rebuilt. Water from the Kuban' River began to flow into the reservoir after the Nevinnomysskiy Canal had been constructed. By means of this water the level of the Veselovskoye Reservoir reached the designed stage. The supply of water from the Kuban' was responsible for the desalinization of the Veselovskoye Reservoir; water mineralization in the reservoir dropped from 7.2 - 26.0 to 1.1 - 1.3 grams per liter (2).

The changes which had taken place in the water and salt regime of soils in regions irrigated by the Veselovskoye Reservoir are being studied by the Southern Scientific Research Institute of Hydro-Engineering and Reclamation YuZhNIIGiM (1). The effect of the reservoir was not studied. To study this problem two profiles were laid out: one profile in the Privol'nyy Farmstead district, Proletarskiy Rayon, Rostovskaya Oblast', and the second profile in the Pokazatel' Farmstead district, Veselovskiy Rayon, Rostovskaya Oblast'.

The Privol'nyy profile was selected for showing the characteristics of the water and salt regime of soils where there were steep banks (average profile gradient was 0.12). Four profile numbers were laid out: 1) soil in transition from dark-chestnut to dark-colored meadow; 2) - 4) dark-chestnut soils; 3) dark-colored soil of depressions. The results of profile studies are illustrated in Figures 1 and 2 and in Table 1.

From Figure 1 we see that the water table gradient runs from the reservoir deep onto dry land. The capillary rise reaches the surface only in a narrow littoral strip (measuring several meters). In the remaining portion of the profile the upper boundary of the capillary fringe is considerably deeper than the layer inhabited by roots. This also affects the character of the soil: signs of increased moisture (meadow formation) are seen only in Profile Number 1, with no signs detected in the remaining profile numbers.

During the observation period (in June), the reservoir level dropped. In 1958 the amplitude of reservoir level, according to data of Rostoblvodkhoz, was equal to 85 cm. If we assume that during the highest water level period the ground waters and capillary fringe rose to this point, then, the upper boundary of the capillary fringe could not reach the zone inhabited by roots.

Prior to construction of the reservoir the ground-water level was several meters (as a minimum) lower, and the water table gradient was oriented towards the Manych Valley. The present water table state is the result of ground-water flow from the reservoir. But after a period of ten years the water table at even a short distance from the shore did not rise to the water level of the reservoir. This indicates that water movement in the adjacent strip is negligible; the low value of the permeability coefficient (8 x 10^{-6} cm/per second) also proves this.

The salt content of soils can be seen from Figure 2 and Table 1. Profile Numbers 1, 2, and 4, have the maximum salt content. In Profile Number 1 the maximum content is in the capillary fringe zone; in Profile Numbers 2 and 4 it is above the capillary fringe. Hence, we can assume that the existing salt profile in Profiles Numbers 2 and 4 is a residual of the water and salt regime which was predominant before the reservoir was built, and is not associated with the present-day water regime. The salts in the soil of Profile Number 3 have been leached.

The ratio between chlorides and sulfates in

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[1] Participating, besides the author, were the students of Moscow State University, L.A. Glukhova, N.A. Shklyarevskaya, and I.G. Chaptykov. General Scientific guidance was entrusted to Professor N.A. Kachinskiy.

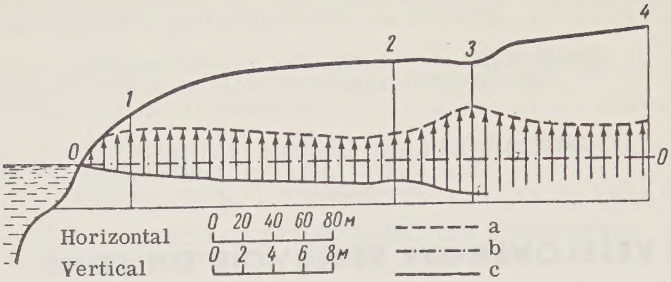

Fig. 1 - Hydrogeological profile at the Privol'nyy Farmstead, June 21, 1958. Profile Numbers 1-4

a - upper boundary of capillary fringe; b - reservoir level, (conditional zero); c - ground-water level.

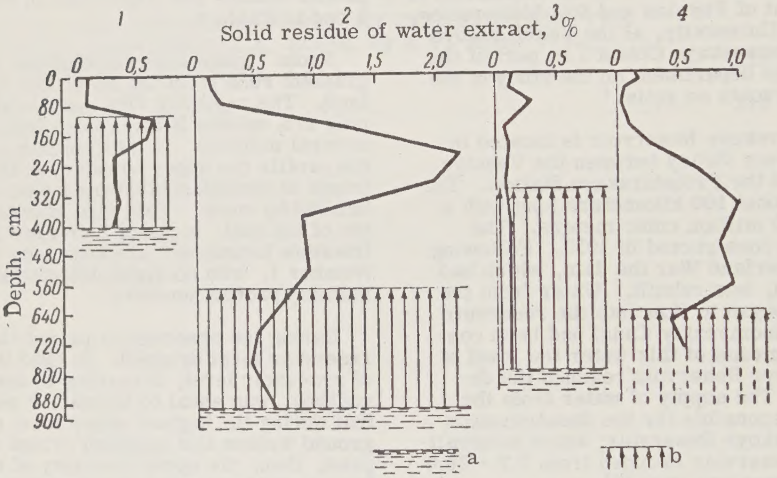

Fig. 2 - Salt content and capillary rise. Profile Numbers 1-4

a - ground water; b - capillary fringe

Profile Number 1 decreases with depth; in Profile Numbers 2 and 4, on the other hand, the ratio increases downwards, that is, in Profile Number 1 (near the shore) secondary salinization takes place; in Profile Numbers 2 and 4 salt distribution is normal for chestnut soils. In Profile Number 3 there are no noticeable changes in the ratio of $Cl:SO_4$, which is the result of its desalinization.

Where there are steep banks and poorly permeable soil materials, there is practically no submergence; only in a small zone along the water-edge measuring several tens of meters do we observe excessive moisture and meadow formation of soils. The salt regime of the adjacent area does not undergo substantial changes either, because only the narrow littoral strip is subject to a small degree of secondary salinization, which, however, after ten years from the date of construction of the reservoir, has not been appreciable.

A second profile was laid out in the district of the Pokazatel' Farmstead, Veselovskiy Rayon, Rostovskaya Oblast' to describe the effect of the reservoir where there are sloping banks (on the first terrace of the Manych). The extent of the profile is 4,435 meters, with a general north to south direction. The northern littoral section of the profile is characterized by a combination of inlets and dry land; geomorphologically, this is the river-bed portion of the terrace; the relief is of gentel slope or broad ridge character. The topography of the southern part of the profile is more level; this part is the lowland (plain) central part of the terrace, which rises evenly towards the main shore.

The basic soils of the profile are the meadow, chernozem-like, medium and weakly-solonchak-like soils (after Rozanov's and Lobova's terminology (3). We find against this background strongl solonchak-like soils and, in places, patches of solonchak as well as soils having a desalinized upper segment of profile (to a depth of 1 meter).

Twelve profile numbers were laid out on the

Table 1

Ratio of chlorides to sulfates

Profile No. 1			Profile No. 2			Profile No. 3			Profile No. 4		
Horizon	Depth, cm	Cl:SO$_4$	Horizon	Depth, cm	Cl:SO$_4$	Horizon	Depth, cm	Cl:SO$_4$	Horizon	Depth, cm	Cl:SO$_4$
A$_1$	5—15	—	A$_1$	5—10	—	I	5—15	—	A$_1$	4—17	—
	20—30	—		26—36	—	II	30—40	—		27—37	—
	50—60	—		43—53	—	III	70—80	0,13		45—55	—
C$_1$	80—90	0,5	C$_1$	70—80	0,99	IV	145—155	0,35	C$_1$	63—73	0,31
D$_1$	110—120	17,3	D$_1$	150—160	0,89	D	165—175	0,39		85—95	—
	160—170	15,4		220—230	0,42		200—210	0,48	D$_1$	150—160	0,29
	220—230	3,70		300—310	0,47		260—270	0,03		200—210	0,32
	280—290	0,60		380—390	1,86		330—340	—		260—270	0,02
D$_2$	340—350	0,47		460—470	1,60		420—430	0,56	D$_1$	370—380	0,20
	390—400	0,97		540—550	1,48		550—560	0,22		490—500	0,90
	—	—	D$_2$	700—710	3,73	D$_2$	670—680	—		600—610	0,39
	—	—		790—800	6,21		790—800	1,12	D$_2$	690—700	4,03
	—	—		900—910	11,28		830—840	—		770—780	4,79

Note: Comma represents decimal point.

Note: In the upper horizons, in view of a low salt content, the ratio of chlorides to sulfates has not been calculated.

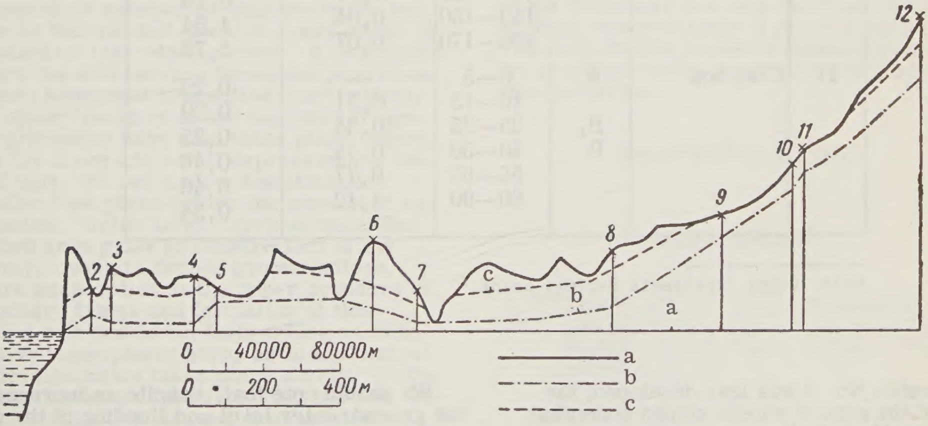

Fig. 3 - Hydrogeological profile of the Pokazatel' Farmstead, Veselovskiy Rayon, Rostovskaya Oblast'. Profile Nos. 2-12

a - water level in the reservoir; b - ground-water level; c - boundary of capillary fringe

profile; Figure 3 shows the profile.

The water table, in general, follows the relief of the area; the depth of the water is small (0.5 - 1.5 meters). The upper boundary of the capillary fringe on flat and elevated areas is situated at a depth of 0.5 - 0.8 meters from the surface; in the depressions the upper boundary comes to the surface. We see near Profile No. 3 a sudden change or break in disposition of the water table. Farther north in the broad ridge river-bed area the water table is almost horizontal, while farther south, in the central lowland or plain area, the water table has a well-developed gradient. If we consider that the water table of the reservoir has risen 10-15 meters above the level of the Manych and that the depressions, which are now inlets or bays, were dry earlier, we might assume that the horizontal state of the ground waters is the result of flooding; prior to construction of the reservoir the sudden change in the water table

Table 2

Ratio of Cl:SO_4 and solid resiude of water extract. The Pokazatel' profile.

Profile No.	Soil	Horizon	Depth, cm	Ratio of Cl:SO_4	Solid residue of water extract, %
2	Clay bog	A	0—10	—	0,06
		B	20—30	—	0,61
			30—35	0,04	0,86
		C	60—70	0,48	0,53
4	Meadow chernozem-like	A	0—10	—	0,13
		B_1	23—33	—	0,28
		B_2	40 - 50	0,04	0,48
		B_3	57—67	0,39	0,64
		C	80—90	0,87	0,82
		D	100—110	1,22	0,78
			110—120	1,09	0,76
			140—160	0,86	0,52
5	Dark-colored, excessively wet	A	0—10	3,35	0,51
		A_1	20—30	2,41	0,24
			40—50	1,76	0,39
6	Meadow chernozem-like	A	0—10	—	0,21
		B_2	40—50	—	0,20
		C_2	80—90	0,88	0,16
		D	100—110	0,08	0,13
			120—130	0,77	0,16
			140—150	0,04	1,54
			160 - 170	0,07	1,72
11	Clay bog	A	0—5	—	0,26
			10—15	0,31	0,29
		B_1	25—35	0,34	0,25
		B	40—50	0,44	0,46
			55—65	0,77	0,46
			80—90	1,12	0,54

Note: Comma represents decimal point.

around profile No. 8 was less developed; the surface of the ground waters sloped somewhat towards the Manych; there was less moisture in the depressions. In this case the flooding effect of the reservoir extended about 2.5 kilometers; further, in the central part of the terrace, the position of the water table did not change.

The permeability coefficient of the soil in the profile is equal to 5 x 10^{-4} cm per second (0.43 m per day). The permeability coefficient is small; yet, a certain low filtration into the banks may take place. The water table gradient is proof of the direction of ground water flow from the main shore towards the reservoir. Hence, flooding is, in the first place, the result of the bearer of ground-water flow and, to a certain extent, of water movement from the newly-formed inlets or bays, which jut deeply into the shores.

We should note that, despite an increase in the ground-water level and flooding of the depressions, the river-bed portion, as a whole, owing to the broad ridge nature of the relief and excellent drainage, also remains at the present time in a lesser wet state than the central (southern) part of the terrace, where enormous depressions accumulate surface runoff, as if serving as reservoirs of water for the surrounding areas. This is also confirmed by direct moisture determinations which we shall not go into in this short article.

Several elements of the relief are distinguished on the profile by the differences in their water regime. These elements are: the elevated and flat areas, where a non-leaching type of water regime typical of dry steppes with comparatively deep ground waters is predominant.

In the depressions the ground waters form cupolas, and the capillary fringe comes to the surface; the surface waters join with the ground waters. Here, two things may happen: a) in the depressions having a small water-collecting area, a small quantity of water, which does not guarantee a leaching regime, may be accumulated; thus, upward flows of soil moisture will prevail here; b) in large depressions having a large water-collecting area, a large quantity of water will ensure the predominance of a leaching regime.

The salt regime of soils (Table 2) is also closely associated with the water regime.

From the content of solid residue of water extract and ratio of chlorides to sulfates, we may draw the following conclusions. At a certain depth we have maximum salt content in soils of level areas. This maximum content is formed as a result of "the checking or pressing back" of the salt by percolating water, the capillary-film movement of solutions from the ground waters, and evaporation within the soil (Profile Nos. 4 and 6). We see in the depressions with a large drainage area a leaching and desalinization of the upper horizons of the profile (Profile Nos. 2 and 11). The drawing of soil solutions toward the surface and the secondary salinization (Profile No. 5) occurs in the small depressions.

If we consider the rise in the water table in the river-bed portion of the profile, we may say that, as a result of constructing the reservoir, the following has developed. There are no essential or substantial changes in the salt regime on the flat and elevated areas either in the central or river-bed portion. It is possible that here the salt horizon formation processes have been somewhat intensified quantitatively on the upper boundary of the capillary fringe. These processes have also taken place before. In both the large and small depressions of the central part, we see a slow desalinization which also took place before the reservoir was constructed. In the large depressions of the river-bed area prior to construction of the reservoir, owing to deeper ground waters, moisture evaporation at the upper boundary of the capillary fringe and formation at this depth of a salt maximum (usbsurface salinization) have taken place; here, as in the central part, desalinization takes place slowly. In the small depressions of the river bed portion, before reservoir construction, a subsurface salinization has taken place; at present we see a surface secondary salinization.

Conclusions

1. The effect of the Veselovskoye Reservoir on the soils of adjacent areas, where there are steep slopes, is negligible and does not extend further than several tens of meters. The barrier created by the reservoir has not yet been levelled; the water table gradient runs from the reservoir deep into the banks (with poor permeable soil materials).

Where we have gently sloping banks, the effect of the reservoir is noted for about 2.5 kilometers. This effect is explained, in the first place, by a barrier of ground and surface runoff and also by direct flow of water from a widely developed network of newly-formed inlets.

2. A meadow formation of soil and a very slight secondary salinization develop on the steep slopes in the narrow littoral strip, which is under the direct influence of the reservoir.

3. The flooding effect of the reservoir within the zone of reservoir influence has been seen in the depressions where water logging processes were intensified. On gently-sloping banks small depressions undergo secondary salinization; depressions which have a large watershed area are being desalinized. There are no qualitative changes in the salt regime on the flat and elevated areas.

4. The observations begun at the Veselovskoye Reservoir are only the first steps in studying reservoir effect on soi;s we must continue our studies to obtain exhaustive data on the problems of the water and salt regime of adjacent areas.

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THEORY OF THE CONDENSATION OF ATMOSPHERIC MOISTURE IN SOIL

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This article represents an attempt to consider critically, summarize, and define in more precise terms modern theory on the condensation of atmospheric moisture in the soil. It takes into account relevant published material.

Of the three known states in which moisture can exist — solid, liquid, and vapor — the last two are most important for practical problems involving the soil. Thus, soil hydrology is primarily concerned with determining the following factors (8): 1) the laws governing moisture movement in soil; 2) the categories of soil moisture; 3) the quantities of moisture in different categories; 4) the interrelations between soil moisture and plants.

While the last three of these are of primary interest to soil scientists, the first also concerns those interested in such related disciplines as hydrogeology and water-supply. Elucidation of these laws would explain the origin of underground water and establish principles for designing devices to take the moisture from the air and make it available for economic purposes. This task is also connected with the physics of the air layer near the ground — a study which has not been receiving sufficient attention (9).

Usually, this whole problem is considered separately for the liquid and vapor phases. The reason is that, in the case of the vapor phase, gravity is not taken into account.

In the upper part of the ground to a depth of several tens of meters, the force of gravity and consequently the pressure of the air and the vapors it contains are constant.

There are three points of view on the movement of the liquid phase (moisture movement in the soil when the moisture content exceeds its maximum hygroscopic capacity).[1] The first, held by L. Lebedev (4), emphasizes molecular forces; the second, that of Dolgov (2), emphasizes capillary forces; and, finally, Rode (8) believes that a combination of these two theories could offer the best solution.

A detailed description of the laws of moisture movement in the vapor phase (until the maximum hygroscopic capacity of the soil is reached) can be found in the works of Rode (8) and Dolgov (2). A new approach to this problem has been suggested by Kolyasev (3).

At present a number of other published studies on the subject is also available. They will be discussed later.

The lower limit for the moisture content of the soil, or any solid, is the completely dry state. Vapor molecules that hit the surface of solid particles (soil) are retained by adsorption forces as a film. This process continues until the energy of thermal molecular movement does not exceed the energy of adsorption. According to Sochevanov (10) the maximum limit of adsorption is achieved at a pressure close to saturation. However, this is not a very precise concept. According to Freyndlikh (8), the process of adsorption is complete when the relative humidity of the atmosphere reaches about 40%. A further increase in the amount of vapor in the pore space leads to supersaturation and formation of fog. At this point multilayer sorption of these water molecules begins; this Lebedev (4) calls "molecular condensation."

According to Lykov (5), this phase is subject to the law of moisture conductivity, which states that the amount of moisture moving in unit time over unit area with the same moisture content is directly proportional to the gradient of moisture concentration. However, this movement can continue only as long as there is a certain inequality, i.e., as long as the relative humidity of the atmospheric air φ is lower than a certain relative critical molecular moisture content φ c.m. (See below).

When φ equals φ c.m., capillary condensation begins over the entire surface of the walls of the soil capillaries.

It should be noted that the law of moisture conductivity holds only under isothermal conditions (when the temperature is everywhere constant and equal). When a thermal-gradient is present, thermal condensation is superimposed on this process.

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[1] A. A. Rode defines maximum hygroscopicity (MH) as the amount of moisture, in % of dry soil weight, adsorbed by the soil from air with a relative humidity of 94%. The MH is an arbitrary quantity.

According to Lykov, a thermal-gradient makes the operation of the law of moisture conductivity more complicated by adding the new factor of thermal-moisture conductivity: the movement of moisture parallel to the flow of heat (from warm to cold areas). It is a complex phenomenon which includes diffusion of vapor or liquid in the direction parallel to the flow of heat (thermal-diffusion) and capillary moisture movement in the same direction.

When changes in moisture content and temperature are involved, we are dealing, not with the law of moisture conductivity, but with the law of thermal-moisture conductivity. The latter represents a generalization of certain known laws pertaining to the movement of vapors and liquids in porous colloidal materials. However, when there is air in the pores of a body containing little moisture (or when it is a coarse porous body), the law of thermal-moisture conductivity needs to be adjusted. The value of thermal-moisture conductivity is in this case negative, indicating that moisture is moving as vapor against the flow of heat (from cold to warm areas) because of the effects of the relative thermal-diffusion. In a mixture of gases, changes in temperature cause heavy gases to move parallel to the flow of heat (from warm to cold areas) and light gases in the opposite direction (from cold to warm areas). In our case this means that air — a heavier gas (adjusted molecular weight, 29) — will move down along with the flow of heat. The lighter gas — water vapor (molecular weight, 18) — will move up along the capillary walls. Vapor from the warmed surface layer may, in turn, form a downward flow. Thus, the two opposite flows of vapor may meet below the surface zone of evaporation, causing supersaturation and condensation. Onchukov's (7) experiments, conducted under natural conditions, illustrate this theory.

It should be remembered that the temperatures of the soil atmosphere and the soil particles constituting the walls of the pores usually are not the same. Thus, when the soil is heated from above, two more possibilities may develop, depending on whether the temperature of the soil air is lower or higher than that of the soil particles. In the former case, the humid air close to the walls will move up and the air in the middle of a pore will move down. During the process the air close to the walls will be enriched in vapor because of it, relative diffusion by condensation, while the air in the middle of a pore will be direr. In the latter case the movement of the air close to the walls and the air in the middle of a pore will be reversed. And, as a result, the former will be drier and the latter enriched in vapor.

Thus, moisture condensation is taking place n some of the soil horizons and evaporation n the others. This is accompanied by a continuous interchange between the soil and atmospheric air.

The thermal condensation described will continue until such time as the correspondingly increased molecular forces of water molecules situated directly opposite each other in a capillary begin to interact. Then the capillary will e closed by a film with a concave meniscus.

If the critical value of the relative humidity of the soil air is greater than $\varphi_{c.c.}$ (critical capillary), capillary condensation would begin even on this concave meniscus. And if it is lower than $\varphi_{c.c.}$, then there would be evaporation from this meniscus.

According to Rode (8), this $\varphi_{c.c.}$ is about 80%. Morozov (6) suggests that it be expressed mathematically as follows.

We know that the height to which water will rise in a capillary is determined by the Laplace formulas as follows:

$$h = \frac{2\cdot\delta}{r\cdot\Delta\cdot g}. \qquad (1)$$

Here δ is the surface tension; r is the radius of the capillary, Δ is the density of the liquid; and g is the acceleration of gravity.

Let P designate the pressure of saturated vapor near the flat water surface; and Ph, this pressure at a certain height (h).

Then Ph will equal:

$$P_h = P - \gamma\cdot g\cdot h, \qquad (2)$$

where γ is the density of the vapor. Now, substituting h from Formula (1), in Formula (2), we get:

$$P_h = P - \frac{2\cdot\delta\cdot\gamma}{r\cdot\Delta} \quad \text{(Thompson Equation).} \quad (3)$$

By dividing Equations (2) and (3) by P, we will obtain a certain relative humidity of the capillary air. This is known as the critical capillary humidity and is written as $\varphi_{c.c.}$

It is expressed by the following formula:

$$\frac{P_h}{P} = 1 - \frac{\gamma\cdot g\cdot h}{P} = 1 - \frac{2\cdot\delta\cdot\gamma}{\Delta\cdot r.P} = \varphi_{c.c.} \qquad (4)$$

If the relative humidity φ of the soil atmosphere in a capillary is greater than this critical capillary humidity, obtained from Formula (4), i.e., $\varphi > \varphi_{c.c.}$, then condensation will occur on the meniscus of this capillary. And if it is smaller, then evaporation will occur instead of condensation. It follows from this that even slight preliminary moistening ("moisture charge") of the soil capillaries should increase φ over $\varphi_{c.c.}$ In this case there would be capillary condensation leading the appearance of liquid water as drops.

Now let us establish the relation between $\varphi_{c.c.}$ and $\varphi_{c.m.}$ For this purpose we can use Laplace's Equation for the pressure of the surface liquid layer which effects water movement. It is as follows:

$$P = k + \delta\left(\frac{1}{R_1} + \frac{1}{R_2}\right). \qquad (5)$$

Here R_1 and R_2 are the radii of curvature of the meniscus as measured for two perpendicular sections. The radius directed toward the liquid has a positive value and the radius directed away from the liquid has a negative value; k denotes the pressure of the surface layer of the liquid when the surface is flat; and δ is the surface tension.

Taking into account molecular forces, we may note that there should be a reduced pressure on the concave menisci. Since there are characterized by negative radii, the Laplace Formula could be used to draw the following conclusions:

To simplify our equation, k can be eliminated as a constant. Then the additional (relative to a flat surface) pressure of capillary forces on the curved liquid surface can be expressed as follows:

$$R_{c.f.} = \delta \left(\frac{1}{R_1} + \frac{1}{R_2}\right). \qquad (6)$$

With cylindrical surface wall of capillary with molecular condensation, one of the radius (capillary height) becomes infinity and equation (6) is:

$$P_m = \frac{\delta}{R_1}. \qquad (7)$$

With equatal radii values of surface meniscus, with capillary condensation, equation (6) is:

$$P_c = \frac{2 \cdot \delta}{R_1}. \qquad (8)$$

Equations (7) and (8) show that $P_m < P_c$.[2] Thus, by using Thompson's equation, we may write:

$$\frac{P_m}{P} < \frac{P_c}{P} = \varphi_{c.\,m.} < \varphi_{c.\,c.} \qquad (9)$$

In other words, when molecular forces ($\varphi_{c.\,m.}$[3]) are operating, the value of the critical relative air humidity is smaller than when capillary forces ($\varphi_{c.\,c.}$) are operating.

As we have noted, capillary condensation in the soil will continue as long as $\varphi > \varphi_{c.\,c.}$, provided that the atmosphere is sufficiently saturated with water vapor. Under natural conditions this condensation may be reduced for the following three reasons (11): first, when the relative humidity of the soil atmosphere decreases and its temperature rises because the ground has been warmed by the sun's rays; second, when the surface tension decreases because of this increase in the air temperature; and third, when the capillary in question is conical.

Condensation stops and evaporation starts in pores in which menisci have curvatures insufficient (owing to large diameters in the upper part of the capillaries) for saturation of vapor molecules.

Since the atmosphere is colloidal in nature, it would be safe to assume that, by relative thermal diffusion, redistribution of vapor also occurs in the air layer near the ground. By analyzing this process, which has been shown to occur in the soil and presumably takes place in the air layer near the ground, we come to the following conclusions.

Investigating the possibility of intrasoil condensation, Lebedev (4) determined the directions in which water vapor moves in the soil. To do so, he first established the saturated vapor tensions at the temperatures prevailing in the different soil layers. When these vapor tensions are directed oppositely, then condensation must occur in the layer in which they meet.

But this means that, when there are two opposite flows of water vapor moving because of relative thermal diffusion, condensation occurs in the layer in which they meet, only if the tension of neither is equal to the saturation tension at the temperature of this layer. Let us call such layers "condensation zones." To prove our assumption, let us express the atmospheric vapor tension (i. e., the air humidity) in grams of water per cubic meter of air rather than in mm or millibars. Then we can say that condensation will occur in that layers of the soil or of the air near the ground in which the moisture content of the saturated vapor at the given temperature is smaller than the sum of the absolute moisture contents of the descending and ascending vapor flow plus the moisture content of the layer itself. This factor was noted in our earlier studies (12, 13). It assumes special importance when considered in the light of the physics of the air layer near the ground. The condensate precipitates in drops on the soil surface as a "dew." Because of wind, it may not reach the ground directly below the site of its condensation in the air.

The latent heat of evaporation released during condensation is absorbed through convection by the surrounding air layers.

As we have already noted, because of circulation of moist air in pores, there may occur simultaneously condensation in some soil layers and evaporation in others. In other words, the thermal equilibrium must be constantly balanced. It was also shown mathematically that preliminary moistening ("moisture charge") of the soil capillaries brings about condensation and the appearance of water drops. The importance of previous moistening of the soil (or other porous bodies) in causing condensation was noted by us in a number of earlier experimental studies (14 and others).

In this connection, we can clarify one problem related to water supply. From the literature (15 and others), we know that in ancient times the city of Theodosia was supplied with water from unique structures built on the nearby Tepe-Oba Elevation. They consisted of orderly piles of porous limestone in which atmospheric moisture condensed during the night. The cone-shaped funnels in the center of each such pile must have served as receptacles for the rain-water falling on the surface of the piles. It was this water that moistened the condensors and thus intensified the process of condensation.

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[2] Probably because of an error, V. Morozov concluded from Formulas (7) and (8) (including factor k) that $P_c = (1 + \delta) \cdot P_m$. Using this incorrect value in Equation (4), he concluded wrongly that that "critical moisture level for molecular condensation forces is higher than the critical moisture level for capillary condensation forces" (instead of P_c he uses P_r).

[3] Ratio between the extra pressure of capillary forces at a curved liquid surface with molecular condensation (P_m) and the pressure at the flat surface layer of a liquid (P), i. e., $\frac{P_m}{P} = \varphi_{c.\,m.}$

The effectiveness of the preliminary moisture charge has been known for a long time. It was well illustrated recently when, in anticipation of a drought, some 15,000 hectares of vineyards in the Crimea were irrigated. In this operation holes were drilled and three or four liters of water were applied below the roots of each plant (to a depth of 60 cm) instead of the 50 l that would otherwise have been needed for surface irrigation. As a result of the subsoil condensation-irrigation process, the vineyards were saved (1).

Because of the practical importance and effectiveness of this moisture charging method, the theoretical principles relating the condensation-evaporation process and the physics of the air layer near the ground should be worked out. In other words, we need to answer the following question: What conditions are required for the transfer of moisture from the soil to this layer and vice versa?

The vapor pressure of the water, of course, increases as the air temperature rises. How this phenomenon affects the soil was vividlv demonstrated by Lebedev's experiment (4, Table 16, p. 48). His data are reproduced in Table 1 together with our own additions (the last three columns).

The following conclusions can be drawn from Table 1:

1) An increase in the temperature of the soil atmosphere is accompanied by an increase (almost always proportionately greater) in the vapor pressure.

2) The greater is the moisture content of the soil, the greater (within certain limits) is the relative humidity of the soil atmosphere. This confirms our earlier conclusion that preliminary wetting of the soil ("moisture charge") increases the relative humidity and, thus, creates more favorable conditions for capillary (thermal) and molecular condensation.

3) When the temperature of the soil atmosphere and the vapor pressure increase, the relative humidity also increases at first. But the rate of this increase (earlier readings divided by later readings) diminishes after a certain limit has been reached ($1 < 1.04$; $1.065 < 1.07$; $1.12 < 1.24$).

The last of these conclusions deserves more attention. The phenomenon described can be explained as follows. As the air temperature rises, at some point the saturated vapor pressure (E) begins to rise faster than the vapor pressure (e) (absolute water content). As a result, the relative humidity of the air even begins to drop and the air becomes drier.

This process can be verified in a number of other natural phenomena. Table 2 summarizes some of them. The meteorological data used in compiling this table came from our earlier study (16) concerning two inhabited areas in different geographical regions.

Table 2 indicates that each of these localities showed the following constant correlations during all seasons:

1. During a seasonal rise in air temperature, E increased faster than e;

2. During a seasonal decline in air temperature, E declined slower than e.

Table 1

Parameters of soil atmosphere from A. F. Lebedev's (4) experiment

Soil moisture content, %	Temperature (C°)	Vapor pressure mm/Hg	Relative humidity, %	Number of times increased at each successive reading		
	of soil atmosphere			temperature	vapor pressure	Relative humidity
5,43	10	8,6	94	—	—	—
	17	13,7	95	17:10=1,7	13,7:8,6=1,6	1,01
	45	70,4	99	2,7	5,1	1,04
	70	229,1	99	1,6	3,3	1,00
3,99	17	11,6	81	—	—	—
	35	36,1	86	2,1	3,1	1,06
	50	84,8	92	1,5	2,3	1,07
	65	183,8	98	1,3	2,2	1,065
2,43	10	3,5	39	—	—	—
	21	7,6	41	2,1	2,2	1,05
	45	36,5	51	2,1	4,8	1,24
	60	85,0	57	1,3	2,3	1,12

Note: Comma represents decimal point.

Table 2

Some meteorological indicators and their comparison for two inhabited localities in the USSR

Season	Khodzhent						Season	Site on coast of Caspian Sea					
	e	α	E	β	φ	T		e	α	E	β	φ	T
Winter	3,9	0,55	5,0	0,43	76	1,1	Winter	4,8	0,46	6,5	0,46	76	4,9
Spring	8,3	2,1	13,5	2,7	62	15,8	Spring	7,2	1,5	10,4	1,6	69	11,8
Summer	12,4	1,5	26,7	2,0	47	27,0	Summer	13,8	1,9	23,2	2,2	60	24,6
Autumn	7,2	0,6	12,1	0,45	63	14,1	Autumn	10,5	0,76	14,2	0,61	72	16,6

Note: Here e is the absolute humidity of the air, in mm Hg; E is the vapor pressure of saturated air, in mm Hg; φ is the relative humidity of the air, in %; T is the mean air temperature, in °C; α is the multiplier showing the change in the value of e from season to season; and β shows the change in the value of E from season to season.

Note: Comma represents decimal point.

Consequently, we have the following picture:

When φ exceeds the critical relative humidity, the soil vapor is subject to molecular or capillary condensation. The latent heat of evaporation released during this process warms the soil.

Until recently it has been assumed that this heat tends to stop the process of condensation quickly. But such is not the case. When the temperature rises, the vapor pressure also rises, usually at a faster rate (several times faster than to the corresponding – not the mean – rate of increase in temperature). This can be seen in Table 1. Vapor flows from the atmosphere to the zone of higher temperature because of relative thermal diffusion (see above) and also from adjacent soil areas through perpendicular capillaries. Thus, conditions favoring condensation continue to exist. But because the absolute humidity e increases slower than E, the increase in the relative humidity will eventually slow down or even become negative. The surface tension of the meniscus will decrease, accordingly. Thus, a moment will be reached when φ will be smaller than $\varphi_{c.c.}$ or $\varphi_{c.m.}$ At this point condensation will cease and evaporation will set in, until the soil atmosphere is humified again, either through the process of moisture condensation described previously or through atmospheric precipitation and artificial irrigation.

Conclusions

1. We have attempted to consider critically, summarize, and define in more detail the modern theory of moisture condensation in the soil. We used for this purpose available published data.

2. In defining this theory in more precise terms, we have proved mathematically that preliminary moistening ("moisture charge") is an effective method of intensifying moisture condensation in the soil.

3. We have proposed and explained a new concept of "condensation zones" in the soil and the air layer near the ground.

4. We have worked out the theoretical principles governing the exchange of moisture between the soil and the air layer near the ground.

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MICROELEMENTS IN SEVERAL SOILS AND SOIL-FORMING PARENT MATERIALS OF KAZAKHSTAN

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The great importance of microelements for plant and animal physiology has brought about the need for studying these elements in soils. A study of elements found in a dispersed state in soils has enabled us now to draw several conclusions. We should regard as the most important conclusion the principle established by Vinogradov (1) on the inheritance by the soil of most microelements contained in soil-forming parent materials. The concentration (or deficiency) of elements in soil-forming parent materials and, consequently, in soils, determines endemic deviations and diseases, presence of oppressed types, and other phenomena comprising the specific characteristics of biogeochemical provinces (2). Another important conclusion is the constancy of different behavior of the microelements in the various soil groups (4, 6, 10, 11, etc.).

Thus, a study of microelements in the soils of any region should include, first, the determination of the complex of microelements contained in the soil-forming parent materials and, second, research on microelement distribution throughout the profile of soils typical of a given region. Future research should be aimed at studying the distribution of the separate microelements according to the basic components of soils and soil-forming parent materials, and investigating the types of forms of microelements.

Bearing in mind what has been said, an experiment was conducted to study microelements in the soils and soil-forming parent materials of the natural desert and steppe zones of Kazakhstan. In this regard the content of microelements was determined both in the various genetic horizons of soils and soil-forming parent materials, and in their different separates, in the dry residue of water extracts and in the different new formations of soil. More than 400 different samples were studied.

Microelements were determined[1] using the semi-quantitative spectral analysis method. A reliable sensitivity for determining a large part of the elements is $1 \cdot 10^{-3}\%$; however, the experience of analysts has enabled them to determine the content of many elements by half this value. The accuracy of analysis is ± 30%. The methods of analysis employed do not permit us to determine with certainty the content of elements in each analytical sample. The results of analyses have been expressed as mean values of several determinations. The mean values were determined as the quotient resulting from dividing the sum of the approximate quantitative amount in the samples by the number of samples having a detected (traced) element. A variation curve is constructed to determine the average content when there is a large number of analyses.

The percent of certain microelements is equal to or even less than the reliable sensitivity of the spectral analysis. A quantitative expression for the percentage of the element in such cases is difficult. In this connection we could use a record of the frequency of microelement detection which shows the abundancy of microelements. For this purpose graphs have been constructed where detection frequency of the pertinent element has been plotted along the ordinate expressed in percent of total number of samples.

Microelements in Soils and Soil-Forming Parent Materials of the Desert Zone

We studied microelements in the soils of the desert zone of Kazakhstan within the confines of the Southwest Pribalkhash'ye, primarily in the area of the low-hill and low-mountain system of the Chu-Iliyskiye Mountains, which are, according to Gerasimov (3), the southernmost extremity of the Kazakhstan low hills. The quaternary deposits are the soil-forming parent materials over a large part of the region. Predominant among the genetic types of deposits of this age are the deposits of diluvial and proluvial genesis having a varying content of aeolian origin. A distinctive feature of these deposits is the strong concentration of particle diameters 0.5-0.1 mm and a small percentage of particle diameters <0.001 mm (usually not more than 10%). A certain concentration of detritus from local bedrock is characteristic of the diluvial varieties.

The characteristic of element distribution

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[1] Microelements were determined on a quartz spectrograph in VIMS (All-Union Scientific Institute for Research in Minerals) under the direction of A. K. Rusanov.

Table 1

Distribution of several microelements[a] in the Quaternary deposits of the southwestern Pribalkhash'ye, $1 \times 10^{-3}\%$

Elements	Reliable sensitivity of determination, $1 \cdot 10^{-3}$	Average (of 50 samples) content in Quaternary deposits	Average (of 10 samples of each fraction) content in separates diameters (mm)				Average (of 10 samples) content in dry residue of water extract
			5—3	0,5—0,25	0,01—0,001	<0,001	
Ti	1	226	83	111	122	117	6,7
Mn	1	78	73	63	68	73	5,1
V	1	9,7	6,8	9,4	10	11,7	2,0
Cu	1	4,9	4,3	4,4	5,3	7,0	3,6
Pb	10	12,5	12,5	9,3	9,0	15,0	5,0
Ni	1	2,0	1,1	1,4	2,3	2,1	1,1
Co	1	1,4	0,9	0,9	0,9	1,2	0,5
Zr	1	8,8	13,0	7,5	4,3	4,1	1,0
Ga	1	6,2	6,3	7,1	5,7	5,4	0,5
Yb	1	2,3	3,0	2,3	2,1	1,5	1,0
Ag	0,1	0,5	0,6	0,6	0,7	0,5	—
Ba	50	89	150	211	78	43	30
B	1000	—	—	—	—	—	$n \cdot 10$
Elements in an amount equal to or less than the reliable sensitivity of determination							
Zn	10	5,5	5	5,6	8,9	8,3	—
Cr	10	6,5	5	5	8,8	9,3	5
Mo	1	0,6	0,7	0,8	0,6	0,8	1,9
Sr	100	94	83	83	100	75	200
Li	100	53	58	83	83	89	—
Nb	10	5	5	5	—	5	—
Sn	1	0,6	0,7	0,6	0,7	0,6	—
Be	1	0,8	0,6	0,6	0,7	0,7	—
Sc	5	5	4	5	5	6	—
La	10	5	5	5	5	5	—

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[a] We cannot assign titanium to the microelements by content in soil-forming parent materials and soils. Editor.

Note: Comma represents decimal point.

in the quaternary deposits of the district are shown in Figure 1. The elements are arranged along the horizontal axis from left to right in the order of decreasing frequency of detection in total samples (Ti, Mn, V, Cu, Pb, etc.).

Table 1 gives the average content of elements in the total mass of quaternary deposits and in their basic components. As we can see from these data, many microelements are accumulated in a mass of finely dispersed particles (<0.001 mm in diameter). These particles, according to data from X-ray, thermal, and optic investigations, are basically hydromicas having a varying degree of hydration. These particles were separated for spectral analysis by the sedimentation analysis, as modified by Gorbunov (5), with the reaction of hydrochloric acid and boiling, by which all weakly-bonded microelements were eliminated. Thus, we may assume that microelement accumulation by dispersed particles of hydromicas is explained by stable surface bonds and, by partial introduction of hydromicas into the spaces between the surfaces.

Several microelements are contained in relatively large quantity in the detrital part — Ba, Zr, and, partially, Pb. Such elements as B, Sr, and Mo are concentrated in the dry residue of water extracts.

The soil-forming process has a specific effect on the microelements contained in the soil-forming parent materials. According to Rozanov (8), the northern sierozems are the zonal soil group of the Chu-Iliyskiye Mountain region, while, according to Lobova (7) the gray-brown sierozems are the zonal soil group. Against this background are distinguished mountain masses covered by mountain-chestnut soils. The Takyr-like soils are developed in several dry valleys and depressions between hills. Unique desert soils with a poorly expressed profile are formed on barchane sands and sand dunes.

Microelement distribution throughout the profile of northern sierozems is given in Table 2. From these data we see that the soil-forming process, characteristic of the zonal

Table 2

Distribution of certain microelements throughout the profile of northern sierozems of the Southwestern Pribalkhash'ye (Average data from 20 soil profiles), $1 \cdot 10^{-3}\%$

Genetic horizons	Elements														
	Ti	Mn	V	Cu	Pb	Zn[a]	Ni[a]	Co[a]	Ga	Sr	Ba	Zr	Sn[a]	Yb	Mo[a]
Sensitivity of determination, $1 \cdot 10^{-3}\%$	1	1	1	1	10	10	1	1	1	100	50	1	1	1	1
Humus	200	91,5	9,5	4,5	10,8	7,5	2,0	1,2	5,7	100	86	8,3	0,6	2,2	0,5
Carbonate	160	57	9,5	4,4	10,0	5,5	1,5	0,9	5,1	100	80	11,4	0,7	2,4	0,7
Gypsum	179	69	7,9	3,0	9,2	5,0	1,8	0,8	3,9	66	66	10,0	0,8	1,9	0,9

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[a] Elements not detected in all samples.

Table 3

Distribution of certain microelements throughout the profile of salinized soils of the Southwestern Pribalkhash'ye (Average data from 6 soil profiles), $1 \cdot 10^{-3}\%$

Genetic horizons	Elements														
	Ti	Mn	V	Cu	Pb	Zn[a]	Ni	Co	Ga	Sr	Ba	Zr	Sn[a]	Yb	Mo[a]
Sensitivity of determination, $1 \cdot 10^{-3}\%$	1	1	1	1	10	10	1	1	1	100	50	1	1	1	1
Humus	267	80	11	4	9,1	5	1,7	1,7	5,5	83	50	8,3	0,5	2,0	0,8
20-30 cm	290	86	10	4,2	9,0	5	1,5	1,8	5,2	80	88	8,0	0,6	2,5	0,5
50-100 cm	238	70	10	4,0	10,0	5	1,5	1,5	5,8	88	80	11,2	0,5	2,0	0,5

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[a] Elements not detected in all samples.

Note: Comma represents decimal point.

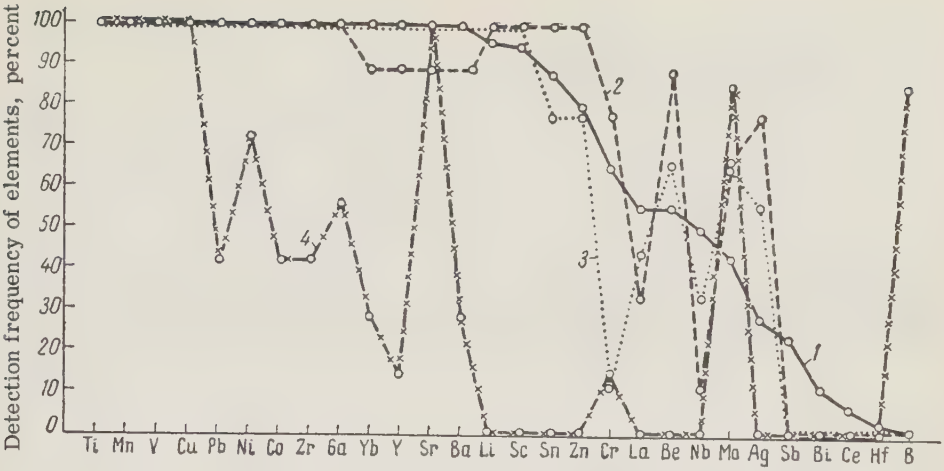

Fig. 1 - Detection frequency of microelements in Quaternary deposits of the Southwestern Pribalkhash'ye.

1 - Total samples of Quaternary deposits; 2 - samples with a fraction <0.001 mm in diameter; 3 - samples with a fraction 0.25-0.50 mm in diameter; 4 - samples of dry residue of water extracts.

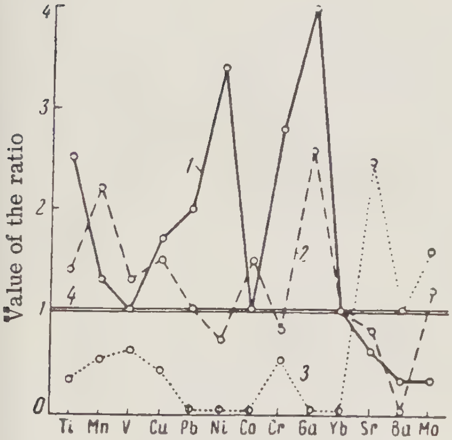

Fig. 2 - Ratio of the content of water soluble forms of several microelements in different genetic-horizons of a profile of northern sierozems to the content of water soluble forms in the soil-forming parent material.

1 - humus; 2 - carbonate; 3 - gypsum; 4 - content of water soluble forms in Quaternary deposits.

oil group, leads to accumulation of many nicroelements in the humus horizon, (Ti, Mn, Cu, Pb, Zn, Ni, Co, Ga, Ba, and partially V nd Sr). Other microelements tend to accumuate in the carbonate horizon (Zr, Yb) or in he gypsum horizon (Mo).

Microelement distribution in the profile of alinized soils has its own specific characterstics (Table 3). Here Mo and, partly Ni and shows the tendency to accumulate in the umus horizon. There is a relative accumulation of many elements in the 20-30 cm layer (Ti, Mn, Cu, Co, Ba, Yb) while other microelements are accumulated in a deeper horizon (Sr, Zr, Ba). The inadequate sensitivity of the method makes it impossible to show the tendency of distribution throughout the soil profile of several elements (for example, Zn).

Considering the importance of determining the water soluble forms of microelements, which are most easily available for plants, we present in Tables 4 and 5 data on the content or percentage of microelements in the dry residue of water extracts taken from northern sierozems and salinized soils.

As we can see by comparing Tables 2, 3, and 4, 5, the water soluble forms constitute a small part of almost all the microelements contained in the soils under study. Moreover, an analysis of the distribution of water soluble forms throughout the profile shows considerably more clearly the tendency of many elements to accumulate relatively in the humus horizon. This is well illustrated by curves showing the ratio of the content of water soluble forms of the separate microelements in the different horizons of the soil profile to the content of water soluble forms of these elements in the soil-forming parent material (Fig. 2). As we see from Figure 2, the percentage of water soluble forms of a large number of microelements (Ti, Mn, Cu, Pb, Ni, Zr, Ga) in the humus horizon of northern sierozems is 1.3 to 4 times more than in the soil-forming parent material, whereas the percentage of water soluble forms of these microelements in the gypsum horizon is less, with the percentage in the carbonate horizon approaching the percentage in the humus horizon. We observe the opposite for a smaller number of microelements (Sr, Mo) — the content of water soluble forms of microelements is 1.5 to 2.5 times greater in the gypsum horizon than in the humus horizon. In the salinized soils the ratios are less clear; however, we do note a

Table 4

Distribution of water soluble forms of several microelements throughout the profile of northern sierozems of the Southwestern Pribalkhash'ye (Average data from 4 soil profiles), $1 \cdot 10^{-3}\%$

Genetic horizons	Elements														
	Ti	Mn	V	Cu	Pb[a]	Zn[a]	Ni[a]	Co[a]	Ga	Sr	Ba	Zr	Sn	Yb	Mo
Sensitivity of determination, $1 \cdot 10^{-3}\%$	1	1	1	1	10	10	1	1	1	100	50	1	1	1	1
Humus	16,4	6,5	2,0	7	10	5	3,7	0,5	2,8	117	10	2,8	0,5	1	0,6
Carbonate	9,6	11,4	2,7	5,2	5	—	0,8	0,8	0,8	162	—	0,8	—	1	2,3
Gypsum	1,8	2,5	1,2	1,5	—	—	—	—	0,5	500	30	0,5	—	—	3,0

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[a] Elements not detected in all samples.

Table 5

Distribution of water soluble forms of certain microelements throughout the profile of salinized soils of the Southwestern Pribalkhash'ye (Average data from 6 soil profiles), $1 \cdot 10^{-3}\%$

Genetic horizons	Elements														
	Ti	Mn	V	Cu	Pb[a]	Zn[a]	Ni[a]	Co[a]	Ga[a]	Sr[a]	Ba[a]	Zr[a]	Sn[a]	b[a]	Mo
Sensitivity of determination, $1 \cdot 10^{-3}\%$	1	1	1	1	10	10	1	1	1	100	50	1	1	1	1
Humus	24	39	2,1	10	8,8	5	2,2	0,9	1,4	150	23	1,5	0,5	1,0	0,8
Lower part of profile	38	11,9	3,2	4,4	6,4	5	1,1	0,6	1,6	1,95	27	2,8	0,5	1,3	1,4

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[a] Elements not detected in all samples.

Note: Comma represents decimal point.

relative accumulation in the surface horizon of he water-soluble forms Mn, Cu, Pb, Ni, and Co.

To supplement the picture of microelement listribution in the soil formation process under lesert conditions, we should note that several elements are being selectively accumulated in he new formations of soil. Thus, for example, n the gypsum and carbonate new formations as ompared with the soil-forming parent material, he percentage of Sr increases several fold, vhereas Mo has the tendency to accumulate in he sulfate-chloride new formations.

Microelements in Soils and Soil-Forming Parent Materials of the Steppe Zone

We have studied microelements in the soils f the steppe zone in the northern Kazakhstan ow hills. According to Storozhenko (9), the uaternary deposits are the basic soil-forming arent material in this area. The genetic types f quaternary deposits in the northern Kazakhtan low hills are characterized by great diersity; they differ from the quaternary deposits f the southern Kazakhstan low hills by a lesser oncentration of particle diameters 0.25-0.01 m and by a greater percentage of particle iameters <0.001 mm (ranging from 15%-30% nd more). The quaternary deposits of orthern Kazakhstan are also characterized by eculiarities in mineralogical composition (a arger percentage of quartz, a lesser percentge of rock fragments, different ratios of heavy nineral fractions. The composition of microlements in the Quaternary deposits of the orthern Kazakhstan low hills also differs omewhat in comparison with the composition of nicroelements in the quaternary deposits of the outhern part.

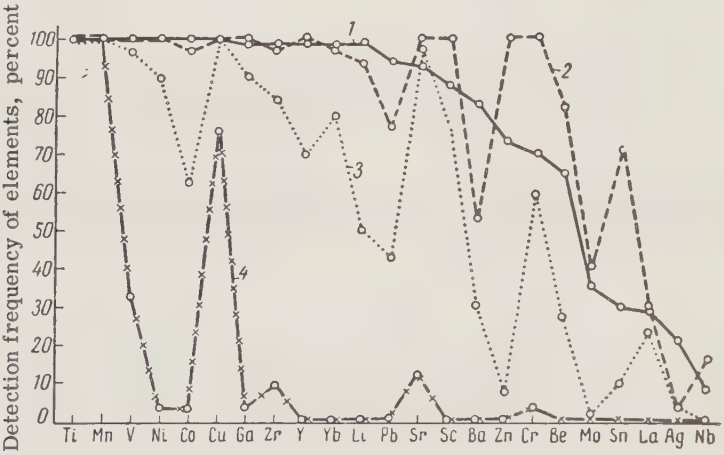

Fig. 3 - Detection frequency of microelements in Quaternary deposits in Northern Kazakhstan

1 - Total samples of Quaternary deposits; 2 - samples with a fraction <0.001 mm in diameter; 3 - samples of carbonate new formations; 4 - samples of fragmental or detrital quartz.

The abundancy of microelements in the uaternary deposits of the district is seen from e data in Figure 3; the average content of microelements in the quaternary deposits and their distribution according to basic components are given in Table 6. We see from these data that in the northern Kazakhstan low hills, as in the southern part, many microelements of soil-forming parent materials are associated to a great extent with particle diameters <0.001 mm (Cu, Ni, Zn, Cr, Mo, Ga, Zr, Sc, Sn, Be). A study of the fraction of particles < 0.001 mm in diameter showed that the fraction was represented basically by hydromicas differing from the hydromicas of the quaternary deposits in the southern Kazakhstan low hills by a greater degree of hydration. A negligible (usually at the limit of sensitivity) percentage of a few microelements was detected in the fragmental or detrital quartz, which in the quaternary deposits of the district amounts to 60%-70%.

The southern (of low humus) chernozems are a zonal soil group in the northern Kazakhstan low hills. Ordinary chernozems are developed on the elevated areas (the Kokchetavskoye uplift); dark chestnut soils (9) are developed in the Pavlodarskaya Oblast'. A complex relief of low hills contributes to the development of this complex character as does the numerous transitional soil types.

Microelement distribution throughout the profile of southern chernozems (of low humus) is seen in Table 7. From the data in this table we see that in the southern chernozems many microelements (Ti, Mn, Co, Ni, V, Zr, Sc) have the tendency to accumulate in the B horizon. The distribution of Ga, Pb, Cu, and Zn is proof of the tendency of these elements to decrease in the soil profile in contrast to the soil-forming parent material. At the same time there is a relative accumulation of Zn in the humus horizon.

The distribution of elements in the solonetz-like soils (two profiles were studied) reveals a decrease in Mn, Ti, Co, V, Zr, Zn, Cu, Ga, Pb in the soil as compared to the soil-forming

Table 6

Distribution of certain microelements in the components of Quaternary deposits of northern Kazakhstan, $1 \cdot 10^{-3}\%$

Elements	Reliable sensitivity of determination, $1 \cdot 10^{-3}\%$	Average (of 70 samples) content in Quaternary deposits	Average (of 40 samples) content in a fraction 0.001 mm in dia.	Average (of 40 samples) content in detrital quartz
Ti	1	405	30	8
Mn	1	112	77	9,6
V	1	12	11,4	0,7
Cu	1	6,8	10,7	0,8
Ni	1	2,1	2,5	—
Co	1	1,2	0,9	—
Zr	1	6,8	7,2	0,8
Ga	1	4,3	6,3	1
Yb	1	2	1,7	—
Ag	0,1	0,5	0,5	—
Sr	100	123	100	100
Ba	100	136	100	—
Elements in amount equal to or less than reliable sensitivity of determination				
Zn	10	8,4	15	—
Pb	10	9,4	7,7	2
Cr	10	8,2	11,2	—
Mo	1	0,7	0,9	—
Sn	1	0,5	0,9	—
Li	100	100	100	—
Be	1	0,8	1,0	—
Nb	10	5	5,0	—
Sc	5	5,2	9,5	—
Y	10	5	5,0	—
La	10	5	5,0	—

Note: Comma represents decimal point.

parent material; at the same time Cu, Pb and Ga are relatively accumulated in the compact horizon.

The unique distribution of microelements was detected in a profile of podzolized soils under pine stands (two profiles studied). In these soils there is a relative accumulation of Zn and Mn in the humus horizon, while in the illuvial horizon there is a relative accumulation of Cu, Pb, Co, Ga, Y and Mo.

In the new formations of soil a selective accumulation of certain microelements was detected: in the iron concretions — Co, Cr, Cu, Be and Mo, in the manganese concretions —

Table 7

Distribution of certain elements throughout the profile of southern chernozems (Average data from 9 soil profiles), $1 \cdot 10^{-3}\%$

Horizons	Elements										
	Ti	Mn	Co	Ni	V	Zr	Sc	Zn	Cu	Pb	Ga
A	205	114	1,4	1,6	10	5,9	5,0	6,7	4,2	6,6	2,1
B	461	134	1,5	2,0	11	8,6	6,0	4,4	4,5	10,0	2,7
C	344	114	1,2	2,0	10	6,3	5,0	7,0	6,6	11,0	4,5

Note: Comma represents decimal point.

a, Pb, Ni, Co and Mo, in the carbonate and ulfate concretions — Sr.

Conclusions

A comparative study of the microelements n soils of the southern and northern Kazakh-tan low hills has enabled us to conclude the ollowing:

1. The geochemistry of microelements in he hypergenesis and soil formation process iffers, which is seen in the adaptation of eparate microelements to be different com-onents of soils and soil-forming parent ma-erials. A large part of the microelements is ssociated with a finely dispersed hydromi-aceous particles (<0.001 mm in diameter).

2. The soil formation processes affect icroelement distribution throughout the soil rofile; microelement distribution has its wn specific characteristics for each group of oils studied; tendency toward accumulation of icroelements in the soil profile is revealed oth for the steppe and desert type of soil for-ation.

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DARK CHESTNUT CARBONATE SOLONETZ-LIKE SOILS OF NORTHERN KAZAKHSTAN

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Widespread within the subzone of dark chestnut soils of northern Kazakhstan, particularly in the Kustanayskaya Oblast' and northern parts of the Akmolinskaya and Karagandinskaya Oblasts are the dark chestnut soils, effervescing from the surface.

These soils were recently described by several authors (3, 6, 8, 10, 12, 13) during study of virgin soils; however, from our point of view, not one of these authors has properly shed light on the problems of the genesis of soils which they studied, or come forth with a complete list of characteristics of the soils' morphological features, physicochemical properties, and peculiarities. In particular, none of these authors showed (as can be seen from their published articles) that these soils, effervescing from the surface, are at the same time solonetz-like. Moreover, several authors, for example, Pachikina (10) stressed the absence in these soils of solonetzization: "the exchangeable cations are, for the most part, calcium. Sodium is hardly found at all, which indicates the absence of solonetzization in these soils." To back her conclusion, Pachikina makes reference to Storozhenko (13), who also did not detect solonetzization in these soils.

In 1954-1956 during selection and study of virgin area, along with students of our department, we conducted soil studies at several new grain sovkhozes in the oblasts mentioned previously. The results of these studies differed radically from data obtained by the foregoing investigators and, from our point of view, have enabled us to deal more thoroughly with the problems of the genesis and property of these soils and the differences between these soils and the dark chestnut carbonate soils of Eastern Ciscaucasia and the Lower Volga Region.[1]

In comparing the dark chestnut carbonate soils of these two areas with dark chestnut soils of northern Kazakhstan which effervesce from the surface, we should, first of all, note the differences in relief under conditions of their occurrence. The dark chestnut carbonate soils of eastern Ciscaucasia and the Lower Volga region occur under undulating-to-hilly plain conditions, occupying the crests of sloping ridges, and are formed on loess-like clay loam, silt clay, eluvium of Permian deposits, in general, on strongly carbonate soil-forming parent materials. Along the slopes and low areas between the hills these soils are replaced by noncarbonate types of dark chestnut soils.

The dark chestnut soils of northern Kazakhstan, which effervesce from the surface, and which are most widespread in the lower part of the Kazakhstan low hills, mainly in the Kurgal'dzhinskaya depression, occupy, on the other hand, the slightly drained lowland strips of plain and are formed on quaternary yellow-brown fine clay loam, underlain near the soil surface by salt-bearing Tertiary clay. As we can see from the following discussion, both these and other deposits have less carbonates than the soil-forming parent materials on which the dark chestnut carbonate soils of eastern Ciscaucasia and the Lower Volga region are formed. In contrast to these areas, on the other hand, the dark chestnut soils effervescing from the surface are replaced by noncarbonate dark-chestnut soils along the more undulating, better drained areas.

The dark chestnut soils of northern Kazakhstan which effervesce from the surface also differ considerably from the dark chestnut carbonate soils of the western sections of the chestnut zone by morphological characteristics. To corroborate this, let us give here the pertinent morphological descriptions of profile numbers.

Profile Number 205. Dark chestnut, carbonate soil, fine clay loam. Site is the kolkhoz imeni Budennogo, Dmitriyevskiy Rayon, Stavropol'skiy Kray. Topography is of the area between the Manych, Yegorlyk, and Kalaus tributaries. An undulating plain. Profile number laid out on the crest of a sloping hill. Virgin land. Festuca sulcata - Stipa steppe. Soil-forming parent material is yellow-brown loess-like clay loam. Effervesces from the surface with HCl.

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[1] We shall conditionally assign to eastern Ciscaucasia that part of Ciscaucasia which lies east of the Stavropol'skoye Plateau. The Saratovskaya, Stalingradskaya and Astrakhanskaya Oblasts and the southern part of the Kuybyshevskaya Oblast' have been assigned by us (also conditionally) to the Lower Volga region.

A 0-25 cm. Dark cinnamon-brown fine lay loam, slightly granular, permeated by rass roots. Transition to following horizon radual.

B_1 25-46 cm. Cinnamon-brown to brown, ine clay loam. Slightly compacted, blocky. 'ransition to following horizon gradual.

B_2 46-85 cm. Dark yellow-brown fine clay oam. Slightly compacted, blocky. Transition o following horizon gradual.

C 85-(150) cm. Yellow brown, blocky, oess-like clay loam with carbonate spots.

Profile Number 350. Dark chestnut carbon- te solonetz-like clay. Site is the grain sov- hoz imeni Gastello, Barynkul'skiy Rayon, Ak- olinskaya Oblast'. Topography is of the area etween the Ishim and Sary-Turgay. Lower art of the plain. Virgin land. Festuca ulcata - Stipa steppe. White wormwood and arsh rosemary seldom found. Soil-forming arent material is yellow-brown quaternary lay loam underlain by red-brown Tertiary lay. Effervesces from the surface with HCl.

A 0-18 cm. Dark cinnamon-brown clay oam, dry, compacted, fissured from the sur- ce. Fine blocky. Transition to following orizon gradual.

B_1 18-57 cm. Dark cinnamon-brown with rown shade, lighter than preceding horizon. ine clay loam. Dry, very compact, fissured, ocky to lumpy. Glossy incrustation along the ces of the structured cleavages. Transition following horizon gradual.

B_2 57-85 cm. Brownish cinnamon-brown ay loam. Somewhat coarser in texture than revious horizon. Compact, coarsely blocky, y. Transition to following horizon clearly xpressed.

C 85-(150) cm. Yellow-brown, blocky clay am. Compact. Numerous spots of carbonates nd gypsum crystals throughout horizon.

In comparing the morphological descriptions the profiles given, we see that the dark estnut carbonate soil of Ciscaucasia is more less friable throughout the entire profile. e compacted illuvial horizon is absent, and, nsequently, we find no morphological signs solonetzization. On the other hand, the dark estnut soil of northern Kazakhstan, effer- scing from the surface, has a very compact uvial B horizon, which is fissured and blocky lumpy. These morphological signs are oof of the solonetzization of this soil.

Let us examine the analytical data in Table for the physicochemical characteristics of the rk chestnut soils of northern Kazakhstan ich we have just described. We see, first of l, from the data in this table that in the ad- rption complex of all dark chestnut soils of rthern Kazakhstan, sodium content is more an five percent of the total of the adsorbed ses, which confirms the solonetzization of ese soils. Moreover, solid residue, quantity chlorides and sulfates, total alkalinity and value, which indicates a weakly alkali reaction of the soil solution, increase with depth in these soils.

The texture of these soils becomes finer with depth; in most cases (Profiles No. 20, 192, and 350) the transitional horizons are the finest in texture. Consequently, results of a particle-size analysis confirm the fact that the soils described have clearly expressed illuvial horizons where a loss from the upper horizons of clay particles takes place. The presence of such horizons, as mentioned previously, of chemical characteristics is further proof of the solonetzization of these soils.

Based on the results of analyses and a study of morphological features we may draw the conclusion that the dark chestnut soils of northern Kazakhstan, which effervesce from the surface, are, to some extent, solonetz-like.

In contrast to these soils, the dark chestnut carbonate soils of Ciscaucasia, as seen from the results of analyses, given in Table 1 (Profiles No. 205 and 394) do not reveal clear signs of solonetzization. There is a very small quantity of sodium in the adsorption complex of these soils. There is no significant increase with depth in the quantity of easily soluble salts nor does the total concentration of alkali rise sharply. Besides, the texture changes very little within the individual horizons and, consequently, a clearly expressed illuvial horizon is missing.

Of the other chemical characteristics which distinguish the dark chestnut carbonate solonetz-like soils of northern Kazakhstan from the dark chestnut carbonate soils of Ciscaucasia, we should mention less carbonates and a different distribution of carbonates throughout the profile.

The highest content of carbonates in the dark chestnut carbonate-solonetz-like soils of northern Kazakhstan is 6.3%, according to given data, while in the dark chestnut carbonate soils of Ciscaucasia the highest carbonate content is 10.2%. Maximum carbonate content in the former group was detected in the transitional horizons, while the carbonate content gradually increased with depth in the second group.

The dark chestnut carbonate solonetz-like soils of northern Kazakhstan also differ from the dark chestnut carbonate soils of other areas in the chestnut zone by humus composition. As we can see from data in Table 2, an increase in the content of fulvic acids, owing to which the ratio of humic acids to fulvic acids becomes narrower, particularly in the illuvial horizons, was detected in their humus composition as compared with the dark chestnut carbonate soils of eastern Ciscaucasia, and the Lower Volga region.

An increase in the content of fulvic acids in humus, like the results of other analyses studied previously, confirms the solonetzization of these soils, because we can see from data of this same table on solonetzes a narrower ratio of humic acids to fulvic acids.

Differences in the values of the ratio of carbon to total nitrogen are further proof of a somewhat different humus composition in the soils which we studied, as compared with the

Table 1

Principal analytical data on dark chestnut carbonate solonetz-like soils of northern Kazakhstan and on dark chestnut carbonate soils of Ciscaucasia

Profile No.	Depth, cm	Name and location of soil	Humus, %	Carbon dioxide, %	pH	Total nitrogen, %	C : N	Particle size analysis		Water extract, %				Base adsorption		
								Diameters								
								< 0,01	< 0,001	Solid residue	Total alkalinity	Cl	SO$_4$	Na, meq.	Na exp. in % of total	Sum of adsorbed bases
192	0—10	Dark chestnut carbonate weakly solonetz-like clay. Kurskiy grain sovkhoz, Akmolinskaya Oblast'	3,95	1,5	7,0	0,50	6,8	66,2	34,6	0,109	0,032	0,004	0,023	2,4	8,4	29,3
	20—30		3,49	2,0	7,2	0,51	6,1	74,6	35,5	0,112	0,030	0,004	0,023	2,6	7,9	32,5
	50—60		2,34	2,1	7,2	Not det'd.		74,7	37,9	0,111	0,032	0,004	0,022		Not det'd.	
	80—90		2,18	3,2	7,4	"	"	67,7	38,3	0,118	0,065	0,008	0,023		" "	
	110—120		0,58	2,1	7,7	"	"	65,9	43,4	0,157	0,067	0,014	0,051		" "	
23	0—10	Dark chestnut carbonate weakly solonetz-like, clay loam. Grain Sovkhoz imeni Kostycheva, Akmolinskaya Oblast'	4,20	1,0	7,2	0,25	9,7	43,4	6,9	0,180	0,020	0,003	0,039	2,4	8,7	27,6
	10—20		3,90	2,0	7,4	0,23	7,5	47,4	13,0	0,200	0,021	0,007	0,052	2,5	7,6	32,4
	50—60		1,20	5,0	7,8	Not det'd.		61,6	39,0	0,260	0,050	0,010	0,040		Not det'd.	
	130—140		0,26	3,0	7,9	"	"	74,2	41,0	0,370	0,090	0,010	0,080		" "	
350	0—10	Dark chestnut carbonate solonetz-like, clay loam. Grain Sovkhoz imeni Gastello, Akmolinskaya Oblast.'	3,72	2,0	7,0	0,24	8,7	35,5	15,0	0,106	0,047	0,008	0,030	2,8	10,2	27,5
	25—35		2,78	3,0	7,2	0,22	7,1	43,2	16,0	0,125	0,057	0,008	0,035	3,2	11,7	28,7
	45—55		1,65	4,0	7,2	Not det'd.		41,4	17,1	0,166	0,071	0,026	0,040		Not det'd.	
	65—75		1,07	5,0	7,2	"	"	39,3	18,2	0,302	0,044	0,125	0,086		" "	
	100—110		0,72	4,0	7,0	"	"	41,5	19,3	0,675	0,025	0,219	0,224		" "	
	125—135		0,29	4,0	7,0	"	"	37,7	16,4	0,663	0,032	0,253	0,238		" "	
20	0—10	Dark chestnut carbonate solonetz-like clay loam. Donskoy Grain Sovkhoz, Akmolinskaya Oblast'	3,60	2,0	7,0	0,31	6,7	33,9	8,8	0,104	0,036	0,003	0,014	4,2	13,8	30,3
	30—40		2,01	3,0	7,2	0,29	3,9	58,8	24,3	0,148	0,085	0,003	0,021	4,5	15,5	28,3
	55—65		1,70	5,0	7,4	Not det'd.		66,4	19,3	0,132	0,046	0,024	0,021		Not det'd.	
	75—85		0,60	3,0	7,0	"	"	53,8	14,9	0,348	0,039	0,156	0,049		" "	
	106—115		0,30	1,5	7,0	"	"	60,1	22,5	0,820	0,029	0,192	0,335		" "	
241	0—10	Dark chestnut carbonate solonetz-like, clay. Kurskiy Grain Sovkhoz. Akmolinskaya Oblast'	4,53	3,2	Not det'd.	0,43	6,0	70,3	30,4	0,105	0,050	0,004	0,008	3,91	11,9	33,1
	13—23		4,15	4,8	» »	0,39	6,2	68,4	38,7	0,127	0,061	0,004	0,008	3,31	11,2	29,6
	35—45		1,77	5,6	» »	Not det'd.		74,2	44,4	0,136	0,073	0,004	0,008	5,14	15,8	32,5
	75—85		1,28	6,3	» »	"	"	74,1	42,6	0,272	0,064	0,098	0,075		Not det'd.	
	105—115		0,60	5,9	» »	"	"	77,1	41,5	0,707	0,035	0,126	0,279		" "	

Note: Comma represents decimal point.

(Table 1, continuation)

Profile No.	Depth, cm	Name and location of soil	Humus, %	Carbon diozide, %	pH	Total nitrogen, %	C : N	Particle size analysis		Water extract, %				Base adsorption		
								Diameters		Solid residue	Total alkalinity	Cl	SO_4	Na, meq	Na exp. in % of total	Sum of adsorbed bases
								<0,01	<0,001							
205	0—10	Dark chestnut carbon-	3,94	2,1	7,0	0,21	10,5	53,0	9,5	0,068	0,026	0,006	0,012	0,70	2,7	25,7
	25—35	ate fine clay loam.	3,21	3,3	7,2	0,20	9,3	52,3	7,5	0,060	0,024	0,008	0,014	0,80	3,5	22,7
	40—50	Dmitriyevskiy Rayon,	1,87	5,8	7,4	Not det'd.		49,3	9,3	0,100	0,034	0,006	0,014		Not det'd.	
	70—80	Stavropol'skiy Kray.	Not det'd	7,8	7,4	" "		52,0	8,0	0,050	0,041	0,006	0,018		" "	
	140—150		" "	9,5	7,6	" "		48,7	9,5	0,098	0,044	0,009	0,015		" "	
394	0—10	Dark chestnut carbon-	3,64	2,6	7,2	0,22	9,6	58,3	12,8	0,098	0,032	0,002	0,018	0,40	1,6	25,8
	20—30	ate fine clay loam.	2,75	3,1	7,2	0,16	9,9	61,0	14,2	0,075	0,036	0,004	0,021	0,63	2,4	26,3
	40—50	Budennovskiy Rayon,	1,41	6,3	7,4	Not det'd.		59,0	10,0	0,087	0,028	0,008	0,027		Not det'd.	
	100—110	Stavropol'skiy Kray.	0,31	8,1	7,6	" "		62,2	13,3	0,102	0,040	0,004	0,016		" "	
	150—160		0,21	10,2	7,8	" "		52,3	11,4	0,156	0,042	0,010	0,030		" "	

NOTE: Comma represents decimal point.

dark chestnut carbonate soils of other areas of the chestnut zone. In the dark chestnut carbonate solonetz-like soils of northern Kazakhstan, this ratio, as data in Table 3 show, is on an average far narrower than in similar soils of eastern Ciscaucasia. Hence, we may conclude that humus in the first group of soils is richer in nitrogen than the humus in the second group.

As we see from all these data the dark chestnut soils of northern Kazakhstan effervescing from the surface differ significantly by several morphological features and physicochemical properties from the dark chestnut carbonate soils of other areas of the chestnut zone thus revealing a clear solonetzization. As a result, we cannot associate them with the dark chestnut carbonate soils of these regions or give them the same name, as the previous authors have done. We consider it advisable to call these soils dark chestnut carbonate solonetz-like soils.

In comparing our analytical data with those of other authors, the question may arise as to why these authors did not bring out the solonetzization in the soils described. This may be explained by the fact that in most of the articles (3, 6, and 12) which we cited, we were missing data on the determinations of adsorbed bases. Only in the article by Pachikina (10) are there given results of adsorbed sodium determinations carried out for samples from only one profile where there was almost no adsorbed sodium. We cannot, of course, make any generalizations from analyses of samples taken from only one profile. We did manage to detect the presence in these soils of large quantities of adsorbed sodium; sodium determinations were made using the Godlin method, which, from our comparative data, should be regarded as the most appropriate for carbonate soils.

The genesis of dark chestnut carbonate solonetz-like soils of northern Kazakhstan is totally different from the genesis of dark chestnut carbonate soils of eastern Ciscaucasia and the Lower Volga region. The dark chestnut soils of northern Kazakhstan formed under slightly drained plain conditions on less carbonate soil-forming parent materials and being originally solonets-like, have become gradually enriched by carbonates. During the wet period, chiefly in the spring when the snow melts, the water which percolates through the soil as far as the carbonate horizons lying comparatively close to the surface partially dissolves the carbonates. When a hot and dry period sets in, the reverse happens — soil solution moves upwards through the soil capillaries with carbonates and during moisture evaporation the upper soil horizons become enriched with carbonates. Our observations have shown that in early spring, during heavy moisture, the dark chestnut soils scarcely effervesce from the surface at all. In the summer and, especially, in the fall, we find a clear effervescence on the soil surface. The carbonate migration process is further borne out by the fact that the maximum carbonates in all cases is observed not within the subsoil, but in the transitional horizons. Within the subsoil the carbonate percentage may be very small. The carbonate content is especially low in the C horizon of Profiles No. 20 and 192, where, in the first case, there were fewer carbonates detected in the subsoil than from the surface.

Table 2

Group composition of humus of dark chestnut soils and of solonetzes in various regions of the chestnut zone

Profile No.	Depth, cm	Name and location of soil	Carbon, %	Humus composition, %			Ratio of humic acids to fulvic acids
				Humic acids	Fulvic acids	In-soluble residue	
6	0—10	Dark chestnut carbonate solonetz-like fine clay loam. Osokarovskiy Rayon, Karagandinskaya Oblast'	2,23	30,3	30,3	24,7	1,0
	15—25		0,89	40,6	30,5	29,6	1,3
1	0—10	Dark chestnut carbonate. Mozdokskiy Rayon. Severo-Osetinskaya ASSR (data by Suslova [15])	1,99	41,7	22,1	26,7	1,9
	30—40		1,39	39,5	22,3	28,1	1,7
45	0—15	Dark chestnut. Saratovskaya Oblast'. (data by Kononova [7])	1,82	33,5	19,8	26,4	1,7
	30—45		1,06	25,5	20,8	31,1	1,4
20	0—7	Solonchak-like solonetz. Nezhinskiy Grain Sovkhoz. Kokchetavskaya Oblast' (author's data).	4,35	28,7	19,7	27,6	1,4
	7—18		2,48	21,4	25,9	28,6	0,8
	20—30		1,18	24,7	27,5	42,0	0,9
—	0—12	Residual solonchak-like solonetz. Malouzenskiy Station. Saratovskaya Oblast' (data by Kononova [7])	1,23	28,3	30,1	29,3	0,9
	12—22		1,05	26,0	25,7	32,1	1,0
	22—32		0,84	17,9	24,9	33,1	0,7

Note: Comma represents decimal point.

Table 3

Ratio of carbon to total nitrogen in dark chestnut carbonate solonetz-like soils of northern Kazakhstan and in dark chestnut carbonate soils of Ciscaucasia (average data for top horizons)

SOIL	Humus	Carbon	Nitrogen	C:N	No. of samples
	in percent				
Dark chestnut carbonate solonetz-like soils of northern Kazakhstan	4,17	2,41	0,314	7,7	16
Dark chestnut carbonate soils of eastern Ciscaucasia	4,01	2,32	0,227	10,2	20

Note: Comma represents decimal point.

The rise of soil solutions through capillaries of carbonates should occur most intensively on the slightly drained plain, that is, precisely under those conditions in which the dark chestnut soils occur. Such conditions of relief combined with a sharply continental dry climate are the principal reason for the broad distribution within the northern Kazakhstan dark chestnut soil subzone of the dark chestnut carbonate solonetz-like soils.

From studying the problems of the genesis of these soils we may say that their carbonate formation does not depend entirely upon the soil-forming parent material, which may be very very weakly carbonate.

Carbonate formation of these soils represents a phenomenon of secondary character and we may distinguish them as secondary carbonate dark-chestnut soils just as Prasolov (11), Afanas'yeva (1), Bogomolov (2), Nosin and co-authors (9), and several other investigators have distinguishe secondary carbonate chernozems among the carbonate chernozems in the different regions of the chernozem zone.

V. A. Nosin and co-authors (9) regard as primary carbonate those chernozems where "calcium and magnesium carbonates are inherited from the soil-forming parent material (bedrock formation) which has preserved carbonates for a long time even during intensive weathering. Such are the carbonate chernozems developed on the weathering products of dolomites, chalk, limestone, marl and similar materials..." These investigators have assigned to secondary carbonates chernozems enriched by carbonates as the result of some kind of interference or radical changes in soil formation conditions, particularly, a change in the water regime.

We feel that the positions of the authors mentioned are valid with respect to the dark chestnut soils described.

There is, of course, no doubt that the phenomenon of carbonate migration which we described and the formation of similar soils may be observed also in other regions of the chestnut zone: in eastern Ciscaucasia and in the Lower Volga region. And actually, we did come across dark chestnut carbonate solonetz-like soils in Ciscaucasia. Moreover, we might mention that in northern Kazakhstan, too, among dark chestnut soils effervescing from the surface, we may occasionally run into non-solonetz-like or practically non-solonetz-like soils.

However, on the basis of our own observations, and considering the whole complex of natural conditions, and their differences in the separate regions of the chestnut zone, we come to the following conclusions. The dark-chestnut carbonate soils, which have no signs of solonetzization, are predominant in the Lower Volga region and, particularly, in eastern Ciscaucasia, while, on the other hand, (as pointed out earlier) the dark chestnut carbonate solonetz-like soils are predominant in northern Kazakhstan and even predominate in places, as, for example, in the Kurgal'dzhinskaya depression.

Establishing the fact that dark chestnut soils of northern Kazakhstan effervescing from the surface are, in most cases, solonetz-like is of great practical importance. If these soils were only carbonate, we could assign them to a single agricultural production group of typical (that is, noncarbonate and nonsolonetz-like) dark chestnut soils, and recommend similar scientific agricultural measures for increasing fertility, because the carbonate (that is, primary carbonate) soils resemble in most of their properties the typical zonal soils.

A totally different situation develops when these soils are at the same time both carbonate and solonetz-like. On these soils, to a far greater extent than on the typical and primary carbonate dark chestnut soils, we need measures to improve the physical properties, especially measures aimed at destroying the compacted illuvial B_1 horizon. Available data shows (14) that deep plowing without moldboard using T.S. Mal'tsev's method is, for example, particularly effective on these soils. Generally speaking, as we know, agricultural techniques employed on solonetz-like soils should differ from those used on soils which have no signs of solonetzization.

Hence, it is clear how important the study of the genesis of morphological features, physicochemical properties, and specific characteristics of soils is when they are being reclaimed for agriculture.

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THE IMPORTANCE OF THE CRYPTO-GEOLOGICAL STRUCTURE OF CENTRAL ASIAN ALLUVIAL PLAINS FOR RECLAMATION PURPOSES

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The resolutions of the Twenty-First Conference of the Communist Party of the Soviet Union, aimed at intensifying the development of all branches of agriculture and establishing an abundance of products and raw materials, has posed before geology very important tasks associated with reclaiming soils of dry regions. As soon as possible we will have to develop and put into practice a plan to improve the land reclamation status of soils in irrigated districts. Much abandoned land, developed as a result of salinization, should be reclaimed in the very near future. At the same time we are faced with resolving the problem of radically improving the land reclamation state of large land areas having an excessive age-long salinization.

Soviet specialists in land reclamation have achieved great successes in controlling salinization of soils. Many difficult problems in the land reclamation phase of soil science conforming to the concrete conditions of irrigated areas have been solved. Solving these problems was possible only when we made a detailed study of the natural conditions of vast geological regions. Such a study has enabled us to conduct a profound scientific analysis of the causes of soil salinization and to lay down basic principles for land improvement measures.

Under central Asian natural conditions reclamation of new areas under grain crops is restricted to a great extent by soil salinization as a result of the high ground-water level. Here hundreds of thousands of hectares of irrigated areas have been subjected to salinization, which leads to a significant decrease in the yield of cotton and other valuable crops.

Under dry climatic conditions, present-day irrigation is impossible without carrying out simultaneously special soil reclamation measures, one of the most important of which is a different type system of drainage construction, that is, a system having an artificial outlet for soil and ground waters from the irrigated area.

One of the main obstacles to the effective operation of drainage installation is the heterogeneous soil materials to be drained as well as failure to take into account certain patterns in soil distribution by area, which depend upon geological structural factors. Under conditions of central Asian irrigated districts, where principal agricultural lands are distributed over large areas of recent and ancient alluvial plains, easily subjected to waterlogging and salinization, soil drainage is particularly important.

The present cost of drainage installations still remains very high, and amounts to a total of 4-5 thousand rubles per hectare, (4). Thus, drainage construction projects should be thoroughly justified.

The basic principle of effective drainage (3) is determined by the predominance of downward flows of water over upward flows, independent of the form in which the moisture moves: whether gravitational, capillary, or film. Thus, we are not compelled to use deep drainage directly on strips which are being reclaimed. Only one fact is important here: to protect the soil from salinization we must create conditions by which ground-water flow will be in a downward direction, and the fresh irrigation waters will dispose of and force out the saline ground waters into the deeper horizons; this disposal of saline ground waters may be realized far beyond the limits of irrigated regions.

Proceeding from this viewpoint of drainage operation in irrigated districts, we must consider that application of closed drainage systems directly on irrigated strips cannot be fully justified.

Applying vertical drainage from this point of view is also impracticable. With this aspect of drainage there arises the problem of disposing of the drained waters. If these waters are disposed of near the drained units, then this will be of no advantage but instead will be detrimental; the drained salt waters will gradually again return, because of infiltration, and total desalinization of the strip will not take place. Consequently, to pump out water using vertical drainage we need a system of long conduits for disposing of the water beyond the irrigated region. At present this method is hardly applicable in light of the acute shortage of conduits. Thus, there remains as the most practical aspect of drainage the open drainage collectors, construction of which under present-day excavation standards is the cheapest. The whole problem leads to selecting a site for the main drainage collectors according to geostructural conditions which determine the water permeability of soil materials, and the natural means of ground-water flow.

In examining data obtained from observing the ground water regime, it is not difficult to see that ground-water level usually rises not because of ground-water spreading but because of the distribution of the hydrostatic pressure surge. Legostayev (5) points out that the distribution of the pressure surge of ground waters takes place in the alluvial deposits of the lower reaches of the Amu-Dar'ya with an average velocity approximately equal to 1, 000 meters per day; in the Golodnaya Steppe in the sandy loam to clay loam soils with a velocity of 800-900 meters per day, and under Ferganskaya Valley conditions in the fine gypsiferous soils with a velocity of 700-800 meters per day. We also obtained similar data in the lower reaches of the Amu-Dar'ya during our studies for hydrotechnical installations in 1950-1953.

These figures indicate not the velocity of horizontal movement of ground-water flow but the velocity of pressure head delivery in the soil from one point to another. The actual velocities of spreading and horizontal flow are measured under the same existing conditions expressed by tenths and hundredths of a fraction of a meter per day.

Thus, the essence of drainage is not reduced to constricting ground waters situated in the presurface layer of ground-water flow, but to removing a certain amount of pressure head, which enables us to maintain the level of ground waters at a depth most conducive to the growth of agricultural crops. Hence, the distances between drains are determined not by the water table depression curve but by the pressure head transmitted throughout the more deeply occurring soil materials, which usually have a double-layered structure on the alluvial plain bottomland clay loam and sandy loam on top, sand of river beds below. Consequently, realization of effective drainage depends not so much on the distance between drains and the depth to which they are laid as on a successful choice for their direction depending upon geological structure.

Standardizing technical conditions during planning calls for the need of establishing a landscape classification in the different zones of irrigated regions. For such a classification the following geomorphological features are usually assumed as a basis: river terraces, watersheds, lowlands, alluvial-delta plains, coastal plains, dry river deltas, etc. However, no one geomorphological feature is sufficiently adequate to describe the character of the soil reclamation conditions. There is still one very important factor which determines within each landscape the properties and capacity of soils for water yield — this is the geological structural design of rocks which lie under alluvium, on which soil is developed.

If rivers, crossing along their way, areas with a different geological structure, reflect this structure in the character of their valleys, then we shall fail to establish any direct relationship in structure between the relief of the earth surface and the deep structural elements on the vast expanses of the alluvial plain of the lower reaches of the Amu-Dar'ya, where basically there is no valley. These relationships can be seen sufficiently clearly in the lithological composition of the alluvial deposits which comprise this plain.

Establishing these relationships will make it possible, with knowledge of well-known structural concepts, to predict the character of the alluvial deposits — their thickness, particle-size composition, salinity, etc., which is of great importance in evaluating land-improvement areas undergoing agricultural utilization and, particularly, in evaluating the possibilities of applying drainage as a means of controlling salinization of soil during irrigation.

The data which we have on hand indicates quite clearly that the alluvial plain at the lower course of the Amu-Dar'ya sustains the effect of recent tectonic movements and that these movements have been acquired from the more remote geological periods, that is, the zones, which correspond to the sags of the more ancient strata, tend to sag even at the present time. Thus, even recent alluvium in these zones is characterized by a finer texture. From facts (2) known to us, the rate of these movements is measured in millimeters per year. For example, from precise geodetic levelling data (6), the average rates of present-day subsidence within the Azovo-Kubanskaya depression are 3-5 mm per year, in the lower reaches of the Terek River, 5-7 mm per year; the uplift of the Srednerusskaya elevation is estimated at 1.5-2.0 mm per year, etc.

Thus, we see that recent tectonic movements may substantially affect gradient changes in river flow and, consequently, textural alluvium deposited by this flow. Hence, there develops a dependence of recent tectonic movements upon the degree of soil salinization, direction of ground-water flow movement, its rate of movement, etc.

From this example of the alluvial plain of the lower reaches of the Amu-Dar'ya, we shall attempt to show the importance of the total geological structural arrangement in planning or designing drainage systems. As a result of geological engineering studies recently conducted here, a large number of holes were drilled and much data accumulated on the texture of alluvial deposits. These data showed that a spatial distribution of the river bed sand facies of alluvial deposits follows definite patterns with respect to texture. The most coarse sandy material is found in zones situated at the extension of the structural uplifts; on the other hand, in zones lying at the extension of tectonic depressions, the alluvial deposits are characterized by finer textural material.

The large area occupied by the alluvial plain, beginning from the lower reaches of the Amu-Dar'ya and Aral Sea and ending in the region of the Verkhne-Uzboyskiy gorge is an ancient valley which had been formed by the river. This river had a fairly low base erosion, because the absolute markings of the ancient erosion water edges within this valley were 60-70 m below the present-day surface of the alluvial plain.

Sand and silt deposits of greenish-gray color with a thickness of about 10 m are basically distinguished in the bed of Quaternary sediments which fill this ancient valley. Higher throughout the profile there occur ancient alluvial sandy clay deposits up to 35 m in thickness.

The Amu-Dar'ya deposits which are situated even higher and comprise the upper part of the alluvial plain profile consist in the upper part of clay loam (floodplain or bottomland facies), with a 3-4 m thickness, and of very fine and fine-grained sand (river bed facies) underlying them. The Amu-Dar'ya deposits are approximately 30-40 m thick.

From mass analyses of the Amu-Dar'ya alluvial deposits it was established that the sands of the river bed facies are heterogeneous throughout the entire area of the alluvial plain. This heterogeneity is determined not only by the structural character of the delta itself and by the principal patterns of sediment accumulation within the estuarial delta plains, but, also, in this case, by abyssal tectonic structure which plays an important part. We arrived at this conclusion based on the fact that sand distribution in the plan having a varying texture conforms to a linear northwest and southeast direction, that is, a direction coinciding with the basic structural elements of the native rocks (bedrocks).

In studying the texture of alluvial sands in the lower reaches of the Amu-Dar'ya, we see that these sands may be, generally speaking, divided into two groups (Table 1).

Table 1

article size analysis of alluvial sands in the lower reaches of the Amu-Dar'ya expressed in percent.

Sand group	Diameter, mm							
	1,0—0,5	0,5—0,25	0,25—0,1	0,1—0,05	0,05—0,01	0,01—0,005	<0,005	Heterogeneity coef.
Group I	—	5,7	35,0	51,0	5,4	0,7	1,8	1,75
Group II	—	—	9,8	67,0	18,5	2,4	2,1	2,48

Note: Comma represents decimal point.

Sands of the first group contain more than 80% of a fraction >0.05 mm in diameter and have a heterogeneity coefficient <1.8. These sands represent, primarily, the river bed facies of the alluvial deposits which are widespread within the zones of tectonic uplifts, and also the masses of aeolian sands.

Similarity in texture between the alluvial sands of the pre-uplifted zone and the moving Aeolian sands is a very noteworthy fact, because areas of the alluvial plain, which are within the zones of tectonic uplifts, are characterized by a more intensified erosion manifested by a small network of gullies. This circumstance favors the development of the deflationary processes and is responsible for the formation of the moving aeolian sands. As a result of the erosion activity the channels or streams of the Amu-Dar'ya, the bed of alluvial deposits on these strips becomes continually more sandy. Here, too, the higher gradients in the river itself contribute to this process.

The sands of the second group contain less than 80% of a fraction >0.05 mm in diameter and are characterized by a heterogeneity coefficient 1.8. The sands of this group represent, primarily, the river bed facies of alluvial deposits, which are widespread within the zones of tectonic sags.

The zones where the sands of the first group are prevalent are characterized by development of dry compact Takyrs and solonetzic soils. In the zones where the sands of the second group are widespread, the soils are salinized considerably more and are chiefly covered by fluffy solonchaks; here, the ground waters crop out and evaporate. Mineralization of ground water and the concentration of salts in it also differ in these zones. In the zones where the alluvial deposits have a coarser texture, the salt concentration in the water usually does not exceed 6-8 g/l; the water here is, for the most part, sodium sulfate. In the zones where the alluvial deposits have a finer texture, salt concentration in the ground waters is 20-30 g/l, and ground-water mineralization is, principally, sodium chloride.

The textural difference of the sands of the first and second group and the presence in zones where sands of the second group are prevalent of a large quantity of gypsiferous sandy and clay loam interlayers affects to a great extent the compactness of structure of the sandy layers and the infiltration coefficient. If the infiltration coefficient for sands of the first group, based on mass field and laboratory studies, has a value of the order of 20 m per day, the infiltration coefficient for sands of the second group will be expressed by a value not exceeding 5 m per day.

A study of the distribution patterns of alluvial deposits having varying textures shows that the zones enriched by more sandy material and zones with a predominance of sandy and

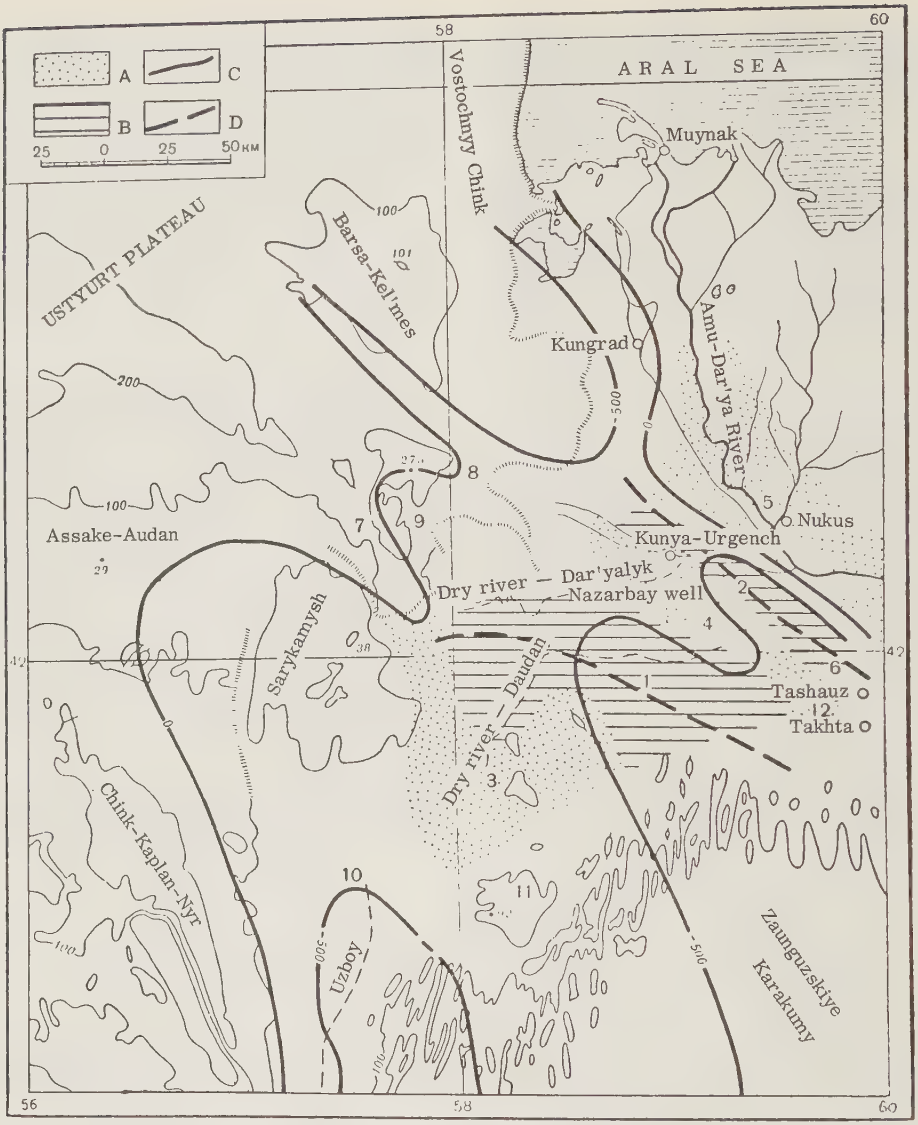

Fig. 1 - A - Fine grained sands of the first group; B - very fine grained sands of the second group; C - isolines of the structural surface of the Paleogene base determined by boring; D - most practical site for main drainage collectors.

Structural elements concealed under alluvial deposits. The depression zones: 1 - Balyklinskaya; 2 - Kunya-Urgenchskaya. Pre-uplift zones; 3 - Koykyrlanskaya; 4 - Nazarbayskaya; 5 - Priamudar'inskaya. Structural elements divided by hypsometric position of the base of Paleogenic deposits at the extension of the crypto zones of the alluvial plain; 6 - Khivinskaya depression; 7 - Shordzhinskaya anticline; 8 - Aybugirskaya anticline; 9 - Cheshtepinskiy sag; 10 - Verkhne-Uzboyskiy sag; 11 - Akhchakainskaya anticline; 12 - Takhtinskaya zone of uplifts.

clay loam interlayers have, basically, a northwest direction.

Figure 1 shows the distribution of the different groups of alluvial sands in the lower reaches of the Amu-Dar'ya and their relationship to the structural plan of native rocks.

On the large area of the Amu-Dar'ya alluvial plain, beginning from Uzboy, we can clearly distinguish in the northeast a large sandy zone with a predominance in the river bed facies of sands of the first group. This sandy zone called the Koykyrlanskaya uplift zone, continues northwest towards the Shordzhinskaya anticline; the Koykyrlanskaya and Akhchakainskaya anticlines are situated to the south-southeast at the extension of the sandy zone. The Tuzgurskaya antiline is situated at the northeast border of this zone. The width of the sandy zone within the lluvial plain is more than 50 km; its course can be traced for 100 km.

From the northeast towards this sandy zone here borders a zone where we observe in the hickness of the alluvial deposits an abundance f clay loam interlayers and a predominance in he river bed facies of very fine grained sand of he second group. In the northwest this zone coincides with the Cheshtepinskiy sag, situated between the Shordzhinskaya and Aybugirskaya nticlines; in the southeast it is characterized by greater thicknesses in the upper Quaternary deposits. We have called this depression zone he Balyklinskaya zone after the name of the Balykly well, where the zone had been first established from a group of wells, by the expedition of the Hydrological Project. The width of the Balyklinskaya depression zone is about 30 km; it is wider to the southeast-up to 0 km. The zone can be tracked for more than 00 km to the northwest and southeast.

In the northeast the Balyklinskaya depression zone is replaced by the Nazarbayskaya zone of uplifts, which is characterized by a sudden predominance in the river bed facies of sands of the first group. This sandy zone extends rom the Aybugirskaya anticline southeast towards the Takhtinskaya zone of uplifts, which s characterized by a decrease in the thicknesses of the Quaternary deposits and by a comparatively close occurrence of the Paleogenic clays. The Nazarbayskaya pre-uplifted zone s about 25 km wide. Its course is traced for 20 km.

Further to the northeast the Nazarbayskaya sandy zone is replaced by the zone where the sands of the second group again are predominant in the river bed facies of the alluvial deposits, and where the clay loam and sandy loam interlayers appear. This zone, called he Kunya-Urgenchskaya depression zone, ends to close in in a northwest direction which s indicated by the decrease in the thickness of he alluvial deposits and by the change in their ithological composition in the direction of and predominance. Toward the southeast the Kunya-Urgenchskaya zone, in all probability, oes not close in but opens up in the direction f the Khivinskaya depression zone, where the lluvial deposits are characterized by more ery fine texture with the presence in the river ed facies of sandy and clay loam interlayers. The Kunya-Urgenchskaya depression zone is bout 20 km wide. It extends southeast and is raced for more than 100 km.

From the northeast the Kunya-Urgenchskaya epression zone is restricted by the Priamudar'-nskaya pre-uplifted zone, with a predominance n the alluvial deposits of sands of the first roup and also outcrops on the surface of upper retaceous rocks along the Amu-Dar'ya.

The relationship between the texture of the iver bed facies of the alluvial deposits and the tructure plan of the native rocks can be seen ot only in the upper Quaternary bed of the mu-Dar'ya alluvial deposits; like relationships re being established also in the lower Quaternary deposits and in the Zaunguzskaya Pliocene sandy-clay alluvial thickness.

Our research (1) has shown that gypsum is accumulated in the bed of alluvial deposits in the water table fluctuation zone and that an increase in the content of gypsum at specific horizons or levels is associated with an earlier higher standing of ground waters. Gypsum is not accumulated everywhere with the same intensity within the water table fluctuation zone. Redistribution of gypsum within the aeration zone and its varying content is associated with a change in subsurface runoff erosion levels. Gypsum accumulation depends not only upon the character of the subsurface runoff associated with the structural plan of rocks which underlie the alluvial deposits; this process is also found to be in direct relationship with the specific characteristics of the structure of the actual layer of alluvial deposits. The gypsiferous state is more indigenous to clay loam materials than to sandy materials. Consequently, the degree of gypsiferousness depends upon the texture of the alluvial deposits and this has a direct relationship also to the structural plan of native rocks, that is, the structural plan, the epigenetic gypsum accumulation, and the texture of alluvial deposits are interrelated.

Thus, within the alluvial plain we have singled out the more gypsiferous zones where deposits with more very fine texture are predominant, and zones less gypsiferous with coarser textured alluvial deposits. The former are difficult to drain; the latter are considerably easier.

The basic conclusion to be drawn from these patterns of change in texture of sandy beds of the alluvial plain as a function of the structural plan of native rocks concealed beneath them is that the recent tectonic movements appear quite intensively in the lower reaches of the Amu-Dar'ya. These movements have, undoubtedly, a differentiated and acquired character. The intensiveness of these movements may be estimated up to 1 mm per year. The fact that in the plan the sandy zones in the alluvial deposits coincide with the positive buried structures of the more ancient rocks is proof of the inheritance of contemporary tectonic movements. Present tectonic movements will form contemporary structural elements along basic northwest lines with these lines having no strictly straight direction.

The foregoing considerations on the soil distribution patterns on alluvial plains enable us to draw the practical conclusion that it would be advisable to plan an irrigation and drainage network in such a way as to arrange the main irrigation canals within tectonic uplift zones and the main drainage collectors within the tectonic depression zones (see Figure 1). In this way the entire irrigation system will be at maximum effectiveness. The percolated ground-water flow from the irrigation canals will continually be directed toward the drainage collectors according to its natural direction. This flow will hydrostatically force the saline ground waters into the drainage collectors.

Such an irrigation system layout will, in the end, lead to total desalinization of vast irrigated regions, to a gradual and universal replacement of saline ground water by fresh water; this will enable crops to use the fresh water in the subsoil and, consequently, to lessen the irrigation water discharge throughout the entire system. Thus, by using one and the same size irrigation canal, the coefficient of its useful operation will be increased.

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EFFECT OF DRAINAGE ON THE FOREST-GROWING PROPERTIES OF PEAT-HUMUS SOILS

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Excessive soil moisture is one of the main factors reducing the productivity of taiga forests. Quite often poor forest growth is due to the fact that prolonged excessive seasonal moisture prevents utilization of a great potential supply of nutrients. This is the case with the peat-humus gleyed soils occupying large areas in regions of calcareous morainic materials in flatlands and in the middle and lower parts of gently sloping small elevations and low ridges.

The peat-humus gley soils develop when there is excessive hard-water periodically, and they characteristically have a peaty layer 5-10 cm thick (sometimes up to 20 cm) immediately below the litter. Below the peat there is a coarse clay loam humic layer (5%-10% humus content) which changes at a depth of 30 cm to a dense, relatively impermeable fine clay loam. Only during dry periods does the water table drop below 50 cm (or below 1 m in some years), while during seasons of heavy rain it rises to the surface.

Tree roots are concentrated mostly in the litter and the peat horizon. They develop poorly in the frequently saturated humic horizon and do not penetrate at all into the fine clay loam horizon, which has the highest total ash contents.

In 1955-1956, at the Kharovsk Leskhoz Vologda Region), a special study was made of he principal properties of peat-humus soils, ncluding the dynamics of nutrients and aeration and also of the distribution of absorbing roots of trees. This study showed that a few very simple drainage measures can greatly improve orest growth on these soils.

In view of this, in May of 1957, we instituted experimental drainage operations on small plots in a new cut-over area and in a yound de-iduous forest. The cut-over area (cut over in he winter of 1956-1957) had formerly held ma-ure spruce (site quality index IV) and a few irch trees, yielding about 250 m^3/ha of wood. Its vegetation consisted of gout weed, forest orsetail, creeping buttercup, spiraea, aconite, *Mnium* species, sphagnum moss, *Dicranum coparium*, *Rhytidiadelphus triquetrum*, and thers. There was almost no undergrowth left fter cutting and logging. For faster information on the effects of our drainage measures on forest growth, we planted young spruce trees on both the experimental and the control plots.

The second experimental site was a drained plot in a young deciduous forest growing on an area burned over 15 years earlier. It consisted primarily of willow with a large admixture of white birch. Below the cut-over tree canopy there was a story of spruce saplings growing very slowly and showing distinct signs of dying (their needles were turning yellow). Here we also had a control plot.

Both areas had similar peat-humus gleyed soils with a thin (5-7 cm) peat horizon. The surface sloped about 1.5°. Ditches 30-40 cm deep were dug at an angle along the contour lines at the upper and lower boundaries. They were then interconnected by a network of transverse drains 10 m apart.

During the growing seasons of 1957 and 1958, we made observations on our drained and control plots. A record was kept of the following factors: fluctuations of the water table; soil moisture content; oxygen content in the ground water; content of available nitrogen, phosphorus, and potassium in the soil; content of ferrous and ferric oxides in the soil; growth of spruce trees; adaptability of spruce trees (on clear-cut area only); content of nitrogen and ash in branches, needles and leaves (birch and spruce trees).

Fluctuations in the water table were determined by means of pipes (20 per each plot) sunk into the soil to a depth of 80 cm and laid out in lines perpendicular to the drains. Samples of ground water were collected four times a month from filters positioned 15 cm, 30 cm, and 50 cm deep, and also directly from the litter layer and peat horizon.[1] Mobile ferrous and ferric oxides were determined in a 1.0-N H_2SO_4 extract with $\alpha\alpha'$-dipyridyl, while available P_2O_5 (Kirsanov's method) and ammonium nitrogen (in 0.5 N H_2SO_4 extract) were determined in fresh soil samples taken from three soil horizons (0-5 cm, litter layer; 10-15 cm, upper part of the humic horizon; and 25-30 cm, lower part of the same horizon). Each sample analyzed was made up of soil from five sampling holes and two or three replications were used. The same samples were used to determine moisture content. Available potassium was determined in dry samples (Kirsanov's method). Samples were taken seven times during the growing season in 1957 and four times in 1958. Material for ash analysis (needles, leaves, new branches) was collected from young trees once in 1957 and three times in 1958. The average samples analyzed consisted of selected material from at least one-hundred different trees of each species.

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[1] The method of sampling the soil and ground water is described in Orlov's article (2).

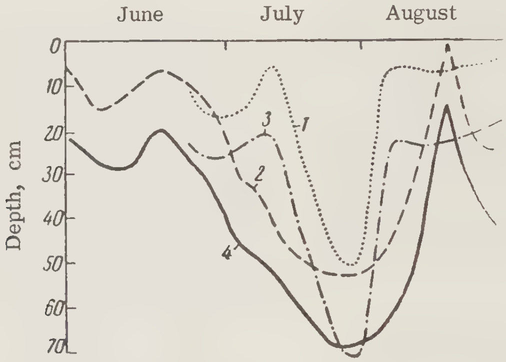

Fig. 1 - Changes in the ground-water level in the clear-cut area during the growing period.

1 - control plot in 1957; 2 - control plot in 1958; 3 - drained plot in 1957; 4 - drained plot in 1958.

In this paper we summarize the results of our observations and present some conclusions on the effectiveness of very simple drainage methods as applied to peat-humus gleyed soils.

A comparison of the water table in the drained and control plots shows clearly that use of the simplest drainage could greatly increase the thickness of the active soil layer recovered from the water-logged portions (Fig. 1).

Findings were similar also in the clear-cut area.

In most cases the water of peat-humus soils contains very little oxygen. The oxygen content of water samples from the 0-30 cm layer of the control plots did not exceed 1 mg of oxygen per liter in 59% of all cases and even less than 0.5 mg/liter in 41% of the cases. Only immediately after heavy rains did the oxygen content sometimes rise to 2-4 mg/liters, and, in very rare instances, to 7 mg/liters. The content was highest in the fall, and sometimes also in the spring, when soil temperatures were low.

No significant differences were observed in the oxygen concentrations of water samples from the soils of the drained and control plots. The oxygen content was higher only after heavy rains, when water rich in oxygen saturated the soil to a considerable depth. In the control plots the penetration of oxygen-rich water is impeded by the high ground-water level. Hence the rain water is simply mixed with the large volume of oxygen-deficient soil water, does not reach the deeper levels, and brings oxygen only to the very top soil layer. On the whole, the oxygen content in the soil water was above 2 mg/liter in 16% of the cases for the control plots, and in 21% of the cases for the drained plots. The small variation of the oxygen content in the water of peat-humus soils when drained is due to its rapid absorption by soils containing large amounts of organic material (5, 1). The improved supply of oxygen to plant roots after drainage results chiefly from the lowering of the water table and not from any increase in the oxygen content of the water.

The faster flow of the precipitation water in the drained areas affected the state of the soil moisture. While the moisture of the litter was not substantially different at the time of drainage and two weeks later in the drained and control areas of the cut-over area, amounting to 450%-490% (of the absolutely dry material), yet in the subsequent period the effect of drainage became very pronounced. The moisture content of the litter on July 2 was 400% on the drained plot and 566% on the control plot. On July 19 it was 212% and 426%, respectively. On August 5 these values were 317% and 525%, respectively; on August 21, 455% at 560%; and on September 9, 426% and 488%. The moisture content of the litter in the drained area in a sapling stand during this same period varied from 376% to 576%, and on the control plot, from 426% to 669%. The effect of drainage in 1957 was less pronounced on the moisture of the humus horizon.

In the second year, 1958, we found a more pronounced difference in the soil moisture contents of the drained and control plots (Table 1). The data of Table 1 show that the moisture content of the litter, which contains more than half of the total mass of spruce roots, is much lower in the drained plot during both the wet and the dry seasons. A very substantial difference is also observed in the moisture content of the upper part of the humus horizon. The moisture content of the lower layer of the humus horizon (25-30 cm) is also appreciably lower in the drained plots than in the non-drained, especially

Table 1

Soil moisture content in the drained and control plots in 1958, in % of absolutely dry matter

Plot	Depth, cm	Date			
		May 21-25	June 27-30	August 8-11	Sept. 19
Clear-cut area, drained	0—5	408	327	178	310
	10—15	129	102	74	62
	25—30	32,8	32,1	20,6	37,9
Clear-cut area, control	0—5	720	571	272	533
	10—15	158	119	90	76
	25—30	33,7	35,2	28,2	37,7
Young forest, drained	0—5	506	423	225	—
	10—15	119	162	72	—
	25—30	26,9	36,1	28,7	—
Young forest, control	0—5	809	614	327	—
	10—15	182	166	120	—
	25—30	34,4	40,5	40,6	—

Note: Comma represents decimal point.

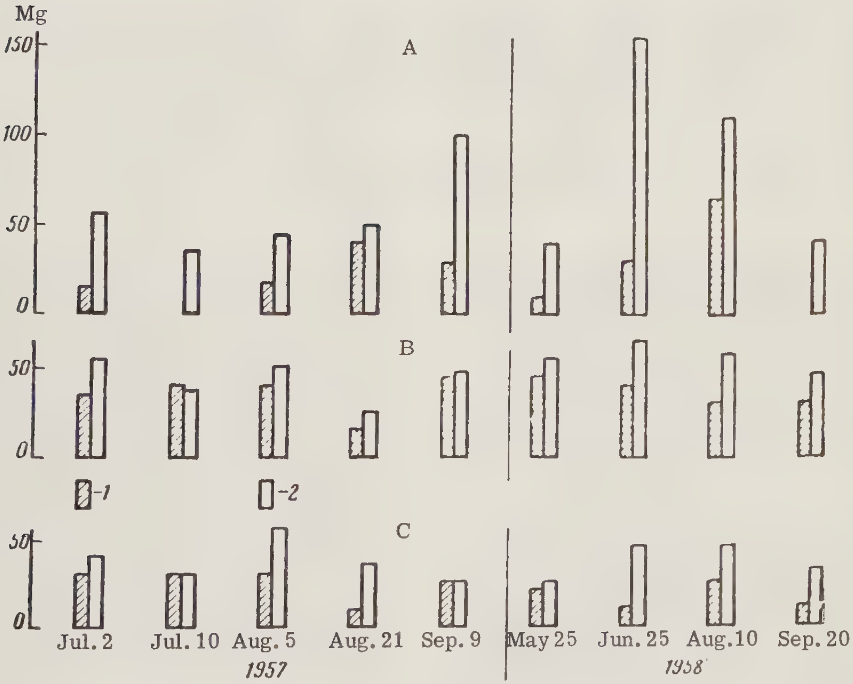

Fig. 2 - Content of mobile ferrous oxide compounds 1) in the drained plot and 2) in the control plot of the clear-cut area (in mg per 100g of dry matter). A - litter; B - 10-15 cm depth; C - 25-30 cm depth.

the young deciduous stand.

The change in the water regime of the drained ts should also improve the soil aeration. One of the indicators of soil aeration is their content of ferrous oxides, which is governed by the oxygen supply to the soil and the speed of its utilization. The quantity of mobile ferrous compounds

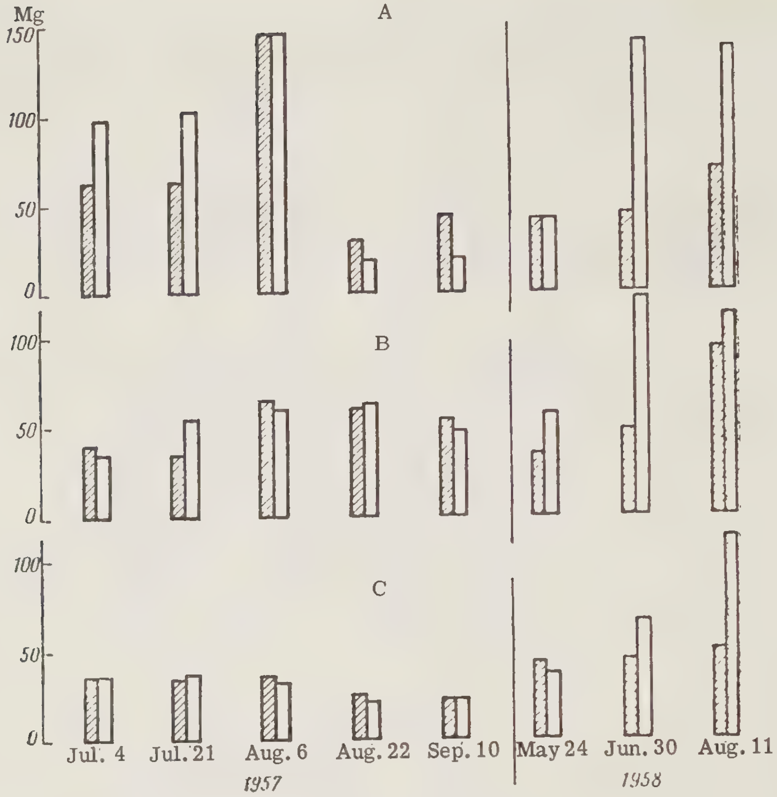

Fig. 3 - Content of mobile ferrous oxide compounds in drained and control plots of the young forest.

See Legend for Figure 2.

in the soil also depends on the total content of mobile forms of iron (ferrous and ferric oxides) in any particular season and on other factors than aeration. No direct relationship has been established between the content of ferrous oxide in the soil and the plant activity (3). Regardless of this, the content of mobile ferrous oxide and its relationship to ferric oxides can be regarded as indicating, to a certain degree, the variation in the availability of oxygen to plants after drainage of excessively wet soils.

The effect of drainage became apparent in the clear-cut area after only half a month: the content of mobile ferrous oxides in the litter was much lower in the drained area than in the control plots (Fig. 2). This difference was apparent to a lesser degree during the growing season of 1957 in the humus horizon. In the young deciduous stand no substantial decrease in the content of ferrous oxide was observed for the drained area as compared to the control plot in 1957 (Fig. 3).

In the second year after drainage very large differences appeared as regards the content of ferrous oxide in the drained and control plots both in the clear-cut area and in the young stand (Fig. 2 and 3). At the end of May, when the total content of ferrous oxide was small (a fact apparently associated with the lack of any considerable warming of the soil), there was little or no difference in the ferrous oxide content (except for the litter in the clear-cut area). Soil warming, by intensifying biological processes, caused a considerable increase in the ferrous oxide content under the extremely wet conditions of the control plots, while in the drained areas the content rose only slightly and in some cases it declined. During this period of increased growth of aerial organs, which is very important in the life of the plants, the drained areas contain, as a rule, two or three times less mobile ferrous oxide than the corresponding soil horizons in the control plots. Larger differences are seen at the beginning of August. In autumn (middle of September), when there is a general decrease in mobile ferrous oxides in the soil, the differences level out somewhat (we have data only for the clear-cut area).

The content of ferrous oxides, expressed in percents of the sum of mobile ferrous and ferric oxides, in almost all cases is less in the drained areas than in the control plots (Table 2), which also indicates a displacement of the oxidation-reduction balance in the favorable direction.

It is interesting to note that, in the period from the end of June to late August 1958, the absolute concentration of ferrous oxide remained

Table 2

Content of ferrous oxide compounds in 1958, in % of total content of mobile ferrous and ferric oxides

Plot	Depth, cm	Date			
		May 24-25	June 25-30	August 10-11	Sept. 20
Clear-cut area, drained	0—5	14	33	62	0
	10-15	62	62	7	21
	25—30	59	36	10	7
Clear-cut area, control	0—5	27	66	52	8
	10—15	71	100	29	28
	25—30	84	75	28	22
Young forest, drained	0—5	26	31	56	—
	10—15	58	37	25	—
	25—30	90	48	18	—
Young forest, control	0—5	36	49	65	—
	10—15	65	100	33	—
	25—30	89	100	28	—

oout at the same level or increased, in spite
the marked decreased moisture content and
e consequent improved aeration. This is ex-
ained by the sharp increase in the general
obility of iron compounds, while the content
mobile ferric oxides increased considerably
ore than the ferrous compounds. The pro-
rtion of the ferrous oxides in the total con-
nt of mobile iron compounds thus declined
arkedly (Table 2). This indicates a favorable
ange in the oxidation-reduction level, despite
e increase in the absolute content of ferrous
ides at depths of 10-15 cm and 25-30 cm. In
e litter there was an increase in the relative
ntent of mobile ferrous oxide, associated in
e drained areas even with some increase in
e absolute content thereof. Certainly, this
nnot be explained by restricted aeration,
nce at this time the moisture content of the
ter was not high. It may be that the large
ntent of ferrous iron is associated with the
lease of iron in the divalent form by the in-
nse breakdown of the organic matter of the
ter (4). It is characteristic that precisely
s period has the single case in which the per-
nt content of ferrous oxide was higher in the
ained area than in the control plot (litter of
ear-cut area, Table 2).

In general the data under discussion on the
ntent of mobile ferrous oxides show con-
sively that in the drained plots there was a
rked improvement in the aeration of the soil
a depth of at least 30 cm.

The data obtained do not permit us to draw
inite conclusions as regards the effect of
inage on the change in the content of mobile
npounds of phosphorus, potassium, and
monium nitrogen. The method used, in-
ving analysis of three mixtures (of five
nples) from each horizon, does not give us
iable average values, since in many cases we found considerable discrepancies between replicates. This was related to the extreme lack of uniformity in the composition of the horizons of peat-humus gley soils. Values were obtained for individual periods which show very definite differences in the content of various available compounds in the drained and control plots. But the changes in the clear-cut area and the young stand are often in opposite directions. Nor do the changes in the individual compounds agree.

From the data obtained we can only conclude that drainage did not cause large changes in the content of available nitrogen, phosphorus, and potassium in the soil. In every case, without more careful studies and analysis of a large number of parallel samples, there is no basis for stating that drainage leads to an increase in the content of available nutrients in the soil. On the contrary, some cases, e.g., ammonium nitrogen in the humus horizon, had a tendency toward a decreased content of available compounds with drainage.

But the absence of substantial changes in the content of available nitrogen, phosphorus, and potassium compounds in the soil does not mean that conditions of plant nutrition are not changed for the better with drainage. The intensified formation of available compounds in the soil is also accompanied by their increased consumption by the plants. We may even expect drainage to be followed by some decrease in the content of available compounds in the soil, since with improved aeration the energy of absorption of nutrients by the plants[2] could increase.

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[2] Rapidly developing herbaceous vegetation was also utilizing nutrients from the soil of the clear-cut area.

Table 3

Content of total nitrogen, P_2O_5, and K_2O in birch and spruce on drained and control plots, % of absolutely dry matter

Dates of sampling	Birch				Spruce							
	Leaves		Shoots		Young needles		Old needles		Young shoots		Old shoots	
	drained	control	drained	control	drained	control	drained	control	drained	control	drained	control
					Total nitrogen							
Sept. 5, 1957	2,00	1,87	—	—	1,15	1,17	—	—	1,12	1,13	—	—
June 10, 1958	1,87	1,73	0,90	0,76	1,65	1,61	0,80	0,88	1,66	1,65	0,78	0,72
Aug. 11, 1958	1,66	1,85	1,03	1,11	1,06	1,00	0,89	1,01	0,68	0,78	0,69	0,68
Sept. 18, 1958	1,73	1,08	—	—	1,57	0,85	1,19	0,84	—	—	—	—
					Phosphorus							
Sept. 15, 1957	1,31	1,14	—	—	0,42	0,48	—	—	0,75	0,44	—	—
June 30, 1958	0,71	0,57	0,27	0,24	0,70	0,65	0,52	0,44	0,82	0,78	0,23	0,24
Aug. 11, 1958	0,87	0,59	0,30	0,25	0,48	0,41	0,57	0,47	0,35	0,34	0,15	0,22
Sept. 18, 1958	1,11	0,99	—	—	0,47	0,42	0,54	0,59	—	—	—	—
					Potassium							
June 30, 1958	1,11	1,03	0,47	0,48	1,39	1,29	0,68	0,64	1,90	1,57	0,59	0,47
Aug. 11, 1958	0,34	0,58	0,66	0,35	0,91	0,79	0,62	0,55	1,09	1,05	0,26	0,45
Sept. 18, 1958	0,54	0,62	—	—	0,61	0,66	0,77	0,55	—	—	—	—

Note: Comma represents decimal point.

Table 4

Content of total nitrogen and P_2O_5 in birch and spruce, % of absolutely dry matter

Forest type	Birch leaves	Spruce needles	Spruce shoots	Forest type	Birch leaves	Spruce needles	Spruce shoots
Total nitrogen				Phosphorus			
Spruce-oxalis	2,14	1,30	1,16	Spruce-oxalis	0,47	0,35	0,36
Spruce-phagnum	1,62	1,17	0,80	Spruce-phagnum	0,26	0,23	0,09

Note: Comma represents decimal point.

A comparison of the data of analyses (Table 3) of the needles and shoots of spruce and leaves and shoots of birch on the drained and control plots in the young stand shows a substantial difference in the ash contents and total nitrogen in the plant tissues.

Consideration of these data indicates above all that there are appreciable variations as regards the plant-tissue content of nitrogen, phosphorus, and potassium during the growing season. The direction of these changes is often not the same for the tissues of birch and spruce. In some cases we find an increase in content of some element in the younger tissues and a decrease in older tissues that live more than one growing season. The dynamics of combined potassium differ from the dynamics of phosphorus and nitrogen.

The object of our paper included the detection of differences in the content of the principal nutrients — phosphorus, nitrogen, and potassium — in the tissues of spruce and birch on drained and non-drained plots. The largest difference in the phosphorous content is observed in birch leaves (Table 3), while an increase was already observed toward the end of the first growing season after drainage (sample taken in the middle of September 1957). Thin birch branches[3] on the drained plot also contain more phosphorus than on the control plot, but the difference is less marked. In the needles and shoots of the current year, as well as in the old needles of the spruce,[4] at almost all times we detect an increase in the phosphorous content on the drained areas. In old shoots (e.g., 2-4 year-old), no increase was found. A marked increase in the total nitrogen content in the tissues of birch and spruce was found at the end of second year of drainage (sample taken in the middle of September 1958). At the other times the difference was small.

The picture was quite varied as regards potassium content. But in most cases there was substantial increase in the potassium content in the tissues of plants growing on the drained plots.

On the whole, the data of ash analysis show that drainage increased the content of phosphorus, nitrogen, and potassium in the tissues of spruce, and especially birch. Consequently, conditions for the uptake of these important elements from the soil improved.

The following may serve as an example of the decreased phosphorus and nitrogen content associated with increased water-logging (Table 4). Spruce needles and shoots, as well as birch leaves, collected from trees in a high-producing spruce-oxalis forest of site quality II on a slightly podzolic soil, contain more phosphorus and total nitrogen than the same tissues of trees growing under excessively moist conditions (sedge-sphagnum spruce forest on a peat soil of site-quality index V).

Thus, despite the fact that direct determination in the soil of nitrogen, phosphorus, and potassium available to plants did not show an increase in the content thereof in the drained soils, data from the analysis of plant tissues show conclusively a definite improvement in the nutrition after drainage.

Drainage had the clearest effect in promoting phosphorous accumulation in the living tissues of plants. We should mention that birch was more responsive to change in aeration conditions than spruce.

Observations on spruce planted in a clear-cut area showed there were no differences in their condition on the drained and control plots in 1957. In the middle of May 1958, i.e., before the beginning of growth, the needles on all the spruces on the control plot had yellowed, and on the drained plot they had a healthier appearance — a normal green or slightly yellowish color. During the growth period the spruce on the drained plot developed lateral and apical shoots[5] with large dark-green needles. On the control plot more than half the plants set out died during June and July; most of the rest of the plants put out only short, poorly developed shoots with small, pale, yellowish needles. Only in the case of several spruce seedlings on slight rises did shoots develop more successfully.

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[3] Shoots of the two preceding years were analyzed.

[4] Samples of old needles were collected from all ranches, except for shoots of the current year.

[5] Terminal shoots did not develop on some of the trees, and their role was assumed by one of the lateral shoots.

No variations were observed in the state of the spruce regrowth on the drained plot in the young stand in 1957. The next year, in the spring of 1958, the bulk of the spruce growth on the drained plot showed a more intense green color in the needles as compared with the paler and yellowish color of the regrowth on the control plot. The growth of the shoots was also higher. The terminal shoots in 1958 on the drained plot were longer by an average of 10% than on the control plot; and for the lateral shoots this value was 28%.

The data given show that draining the peat-humus gley-like soils by means of small ditches markedly altered aeration conditions to a depth of at least 30 cm, improved the ash and nitrogen nutrition of plants, and affected growth as early as the second year. In addition, as the roots penetrated the deeper horizons, the growth became still greater.

In conclusion we should note that we can expect the draining of peat-humus gley-like soils to be more effective in raising the productivity of forests than the draining of excessively waterlogged forest areas with a thick layer of peat. With the use of comparatively simple drainage measures (small ditches), tree roots here can utilize more nutrients in both the organic and mineral horizons. Since peat-humus soils are located on more or less definitely sloping surfaces, their drainage does not require the arduous job of digging large main ditches and the clearing of natural waterways. Observations have shown that the peat-humus gley-like soils receive their excess moisture chiefly from higher-lying areas of the locality. To remove this water we do not need as dense a network of ditches as in the experiment described. By using the techniques of lumbering organizations on concentrated clear-cuttings to establish the networks of ditches, it is possible at small expense to increase substantially the productivity of the new forest generation over wide areas having peat-humus soils.

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ROLE OF SOIL-ADSORBED AMMONIUM IN THE NITROGEN NUTRITION OF PLANTS

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More than 50 years ago the joint efforts of plant physiologists and agricultural chemists led by D. N. Pryanishnikov resulted in the solution of the pivotal problem of the nitrogen nutrition of plants, thus ending a dispute that divided scientists during the second half of the 19th century. It was proved that plants can utilize nitrogen in both forms: in the reduced form as ammonia, and in the oxidized form as nitrates. And in the course of further research the most favorable conditions for the various types of nitrogen nutrition were determined (reaction of medium, complementary ions, concentration, age of plants, and carbohydrate content in plant tissues). At that time Pryanishnikov wrote (16): "Optimum combinations of these conditions for ammonia and nitrate are not the same. If we succeed in finding optimum conditions for both sources of nitrogen, then we must recognize in principle their physiological equivalence. And if we compare them under any given set of conditions, we may find the weight shifting from one source to another depending on these conditions. But the physiological facts, while they are absolutely necessary for us, still do not lead directly to an agricultural solution, because it is only in the laboratory experiment that we can easily create optimum conditions for both sources...."

One of the basic factors in the fertility of a soil, of course, is its ability to satisfy the plant's needs for nitrogen by making it available at the proper time, in sufficient quantity and in the proper forms. Hence it is quite easy to understand why so much attention has been and is being given to the dynamics of the mineral forms of nitrogen. But these studies have not reflected to any great extent the physiological principle of the equivalence of ammonium and nitrate nitrogen in plant nutrition. An enormous mass of data has been accumulated on the dynamics of nitrates in the soil. These data permit us to make statements about the accumulation of nitrates in various types of soils under various conditions of tillage, crop rotation, crop type, fertilization, and in various meteorological situations. Since the NO_3 is not adsorbed on the soil either chemically or physiochemically and is completely dissolved in the soil solution when enough moisture is present, there can be no doubt about its availability to plants (and to microorganisms). It is only when other nutrients, such as phosphorus, are deficient that the utilization of the NO_3 may be restricted. The accumulation of nitrates in itself testifies to the favorable conditions of the soil because the same pH values and the same concentration and composition of the soil solution are favorable both for the growth of the majority of crops and for nitrification. Thus it is only natural to find that the data on nitrate dynamics can always be used successfully to definte the nitrogen regime of the most varied of soils varieties, and to determine the need for the application of nitrogen fertilizers, and to decide the proper time and rate required. Moreover, the nitrate dynamics are very indicative of the fertility of the soil.

The case is different where soil ammonia (ammonium) is concerned. The ammonification is extremely widespread in the soil. Large numbers of microorganisms are adapted to widely different environmental conditions. Yet ammonia is not always accumulated, but rather, only when for some reason it does not undergo further conversion into nitrates. The conditions which inhibit nitrification in the soil and at the same time favor the accumulation of ammonia are many, including a low and high pH values, increased amounts of mobile Al, low levels of base saturation, insufficient aeration, low temperatures, increased concentration of water-soluble organic substances, high bitumen content in the organic matter, etc. Such conditions are present in many forest and bog soils and in the acid podzolic and irrigated chestnut soils, as well as in chernozems during cold periods in spring and fall (23, 14, 10, 21).

Studies of ammonium nitrogen in the soil, while not as numerous as for nitrates, have shown considerable accumulation of ammonia under these conditions (2, 3, 4, 8, 10, 19, 21, 22).[1]

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[1] It should be noted that not all of the data may accurately reflect the soil content of ammonium nitrogen. Because of certain features of the methods used, determinations involving dry samples of certain soils produce results that are too high (12, 11). In our case the same results were obtained from determinations of adsorbed ammonium in moist and dry samples of sod-strongly podzolic soils for sandy loams. But dry samples of clay loams showed a higher content (1.4-1.5 times) than fresh samples.

Table 1

Accumulation of nitrogen in winter rye in the spring in relation to the content of mineral nitrogen in the soil

Preceding use	Mineral N in the 0-40 cm[a] layer, mg/kg of soil				Total N in winter rye plants, g/m²	
	ammonium N		nitrate N			
	April 22	May 6	April 22	May 6	April 29-May 3	May 17-18
Fallow	25,0	10,3	10,9	13,8	1,74	5,12
Stubble	22,1	7,2	1,8	2,2	0,72	1,21

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[a] Sum of N in the 0-20 cm and 20-40 cm layers.

Note: Comma represents decimal point.

Table 2

Mineral nitrogen content of soil during planting of spring wheat and effects of nitrogen fertilizers

Plot	Mineral nitrogen in the 0-20 cm layer, mg of N per kg of soil (May 24)		Spring wheat yield, cntr/ha			Increase in yield from nitrogen, cntr/ha
	ammonium N	nitrate N	without fertilizer	P_s	$N_{an}P_s$	
2nd crop after clearing forest	42,3	4,6	16,2	16,1	21,7	+5,6
Old plowland	21,7	4,9	7,6	6,9	12,5	+5,6

Note: Comma represents decimal point.

A uniform distribution of ammonium nitrogen over the soil profile, sometimes to a considerable depth, is frequently noted as not characteristic (19), in contrast to nitrates. While the reasons are still not clear, in certain cases it may be related to the movement of NH_4 humates along the soil profile (18). But the presence of ammonium nitrogen in the soil still does not necessarily mean that plants have nitrogen available. Undoubtedly much depends on the specific properties of the plants themselves.

The fact that the ammonium cation is strongly adsorbed by the soil must be taken into consideration. The usual method of determining ammonium in KCl extracts of the soil gives the total of the adsorbed and water-soluble forms, but the water-soluble form usually accounts for only a small part of this total. Because so much ammonium is readily adsorbed by the soil, its part in the nitrogen nutrition of plants assumes special importance. Adsorbed ammonium is not leached from the upper layers by precipitation nor does it occur in high concentration. These advantages were noted by Gedroyts and Lebedyantsev (6, 12), as well as by Shmuk (24). However, at that time (30 years ago) there was very little actual data on the presence of ammonium in the soil, so that its considerable importance as a source of nitrogen was largely ignored. (For example, K. K. Gedroyts believed that the content of ammonium did not exceed 0.1 meq/100 g of soil). Incidentally, while this amount (0.1 meq/100 g) cannot affect soil properties, it is by no means insignificant as far as the nutrition of plants is concerned. A concentration of 0.1 meq of N per 100 g of soil amounts to 14 mg/kg or 42 N per ha. Even though we now have factual data, it is still difficult to arrive at definite conclusions. We give two examples from our own observations.

In a study of the nitrogen nutrition of winter crops growing on leached chernozem in Omsk Region (at the Siberian Scientific Research Institute of Agriculture in 1946), we obtained the following data.

As can be seen from Table 1, the ammonium form of nitrogen prevailed over the nitrate, because of low temperatures during early spring. While the amount of ammonium nitrogen was almost the same in the two different types of agricultural land, (fallow and stubble), the content of the nitrate N was much greater in the fallow. Had ammonium and nitrate been equally important as sources of N nutrition, the winter rye would be provided with nitrogen to more or less the same extent on both fields. Since

Table 3

Degree of ammonium saturation in soil

Site of sample collection	Soil	NH_4, mg N per kg of soil	NH_4, meq per 100 g of soil	S, total adsorbed cations, meq per 100 g of soil	Degree of NH_4 saturation, %	Author
Zhdanov Kolkhoz, Tarsk District, Omsk Region	Sod-strongly-podzolic a) cleared land	42,3	0,30	6,1	4,92	Our data (5).
	b) Old plowland	21,7	0,15	7,6	1,97	T. P. Slavnina (19)
Tomsk Zonal Experimental Station	Gray moderately-podzolized forest	32,7	0,23	21,0	1,01	
Siberian Scientific Research Institute of Agricult., Omsk	Leached chernozem	19,6	0,14	43,6	0,32	A. Ye. Kochergin and O. A. Ostroumoya

[a] Conventionally: $\frac{NH_4, \text{ in meq}}{S, \text{ in meq}} \cdot 100.$

Note: Comma represents decimal point.

ctually the difference in nitrogen available to ne crop proved to be very considerable and irectly proportional to the amounts of nitrate ontained in the two fields, it must be conluded that only nitrate served as the primary ource of nitrogen nutrition. This means that, fter a wet autumn, when the content of nitrate the upper layers of chernozem is low, winer crops require a spring application of nitroen fertilizers, even though the soil may conin considerable amounts of NH_4.

The second example pertains to the sodrongly podzolic sandy loam in Tarsk District, msk Region (5). There we determined two rms of nitrogen on experimental and control lots during planting time. Table 2 shows the ata of our observations on the control plots as ompared to the effectiveness of nitrogen rtilizers applied on the experimental plots.

Here again the content of ammonium nitroen turned out to be considerably greater than at of nitrate nitrogen. According to Peterurgskiy's experiments (13), one half of the adrbed nitrogen is available to plants. If we ccept this ratio, we would arrive at the conusion that the 0-20 cm layer contained about) kg of ammonium N per hectare on clearedrest land and about 30 kg/ha in old plowland 'able 2). In view of this considerable difrence between the two fields, it could be excted that the wheat would show a correspondg difference in its response to nitrogen rtilizers. But the results of our experiments oved this expectation to be wrong: the increase in nitrogen contained in the plants was ually high following the application of N_{an} mmonium nitrate) to both fields. Significant, the level of the nitrate nitrogen for these o fields was also equal. Thus, while it ould not be asserted that ammonium nitrogen does not participate at all in the nutrition of plants, it is quite obvious that this form of nitrogen alone cannot satisfy the nutritional requirements nor can its content be used to predict the effects of nitrogen fertilizers.

How should we, then, consider data on the content of ammonium nitrogen, and what is its actual availability to plants under the conditions of its accumulation? As yet, we are not in a position to give a sufficiently conclusive answer to this question.

A number of studies have raised the problem of the availability of adsorbed cations to plants (6, 9, 13, 17, 25). One of the last works of Gedroyts (6), dated August 1932, referred to an experiment in which oats were grown on a chernozem soil saturated with ammonium by NH_4Cl and then washed with alcohol. The oats utilized ammonium nitrogen as readily as the nitrates applied. No check was made, however, of the nitrification of ammonium in the experiment.

Further investigations revealed certain general tendencies, which showed that "...the availability of adsorbed nutrients to plants is determined by very many soil and physiological factors, certain combinations of which may make them completely unavailable." (17, p.32).

What are the factors that may affect the availability of adsorbed ammonium to plants? Here we shall mention only the following which to us seems to be basic: a) the level of saturation of the soil colloids with ammonium; b) the complementary cations; and c) the reaction of the medium.

On the basis of his own experiments and those described by S. S. Yarusov, Ye. I. Ratner came to the conclusions (17) that "...when the level of potassium saturation of the soil is low, its availability to plants decreases, regardless of the nature of the complementary exchangeable cations." In all probability this conclusion can be also applied to ammonium. As Table 3 shows, considering the amounts of ammonium accumulated in the soil, the level of ammonium saturation of the colloids is very low. The ammonium saturation of chernozems is especially low. This may be the primary reason for the marked decrease in the coefficient of utilization of adsorbed ammonium.

It may seem that our premise about the degree of saturation of soil colloids with ammonium ion contradicts the undisputable fact that the ammonium contained in fertilizers, such as $(NH_4)_2SO_4$, is readily taken up by plants even when the amounts of those fertilizers used can provide only a very low degree of saturation. Thus, for instance, 45 kg of N per hectare amounts only to ~15 mg of N per kilogram of soil and ~0.1 meq of N per 100 g of soil. It must be remembered that a certain part of this ammonium, varying in each individual case, may be converted to nitrates before reaching the plant. It may be also maintained that, since fertilizers are never really mixed uniformly and completely with the soil, in some places the level of ammonium saturation is actually much higher than might be expected on the basis of estimates.

The availability of adsorbed ammonium to plants may also be affected by the composition of accompanying exchangeable cations. Thus, for instance, Yarusov (25) and Ratner (17) have established the fact that sodium acts as an inhibitor, preventing potassium and calcium from becoming available to plants.

It is also apparent that, in the vast zone of acid soils, the reaction of the medium is an important factor affecting the availability of ammonium. Studies of D. N. Pryanishnikov and his followers (15), as well as those of foreign scientists have demonstrated that, when the reaction is acid, ammonium is not as good a source of nitrogen as nitrate. It is least effective as a source of N in the pH range (below 5.5) which is unfavorable to nitrification and thus conducive to further accumulation of ammonium in the soil. The available data, however, are not sufficient for a quantitative expression of this relation. And, since we cannot state how much the availability of ammonium is reduced by one or another value of the pH under the natural acid-soil conditions, we are as yet unable to evaluate properly the significance of the amounts of ammonium determined. But it is quite clear that under such conditions ammonium plays a much less important part in the nutrition of plants than nitrate.

The uncertainties in the problem of the availability of adsorbed ammonium, on the one hand, and the recognition of the physiological equivalence of the oxidized and reduced forms of mineral nitrogen, on the other, have resulted in many incorrect evaluations of data pertaining to the content of ammonium in the soil.

For instance, Zaytsev (7, 8), in studying the dynamics of the nitrogen regime in the soils of the northwestern USSR, found that these soils contained large amounts of ammonious nitrogen. But agricultural crops growing on these "nitrogen-rich" soils actually suffer from nitrogen deficiency. Application of nitrogen fertilizers in these regions effects considerable increases in crop yields (1, 7).

Slavnina (19, 20), and Tyumentsev (22) found large amounts of ammonium nitrogen distributed throughout the entire profile of gray forest soils (Tomsk Region) subject to different degrees of podzolization. But we also have testimony to the effect that "...the results of many years of field and greenhouse experiments at the Tomsk Zonal Flax-Growing Experimental Station show that nitrogen fertilizers are quite effective for the majority of crops when applied to dark-gray, gray, and, especially, light-gray soils" (19, p. 84).

While stressing the fact that nitrate and ammonium are not equally available to plants, we have no intention of discounting the ammonium form of nitrogen altogether. Even less are we inclined to agree with those (12) who doubt that ammonium can actually accumulate in the soil. Such assertions have no basis in fact.

Conclusions

1. Plant utilization of the nitrogen contained in adsorbed ammonium depends on a number of physicochemical and physiological factors. Under conditions conducive to the accumulation of ammonium in the soil these factors may exist in combinations which considerably reduce the availability of ammonium to plants as compared to nitrate.

2. Since adsorbed ammonium and nitrate are not equivalent, they should never be lumped together in determining nitrogen. Otherwise, erroneous conclusions may be drawn concerning the actual supply of nitrogen to the plants wrong practical decisions may be made.

3. Further investigations are needed on the availability of ammonium nitrogen to plants under the specific conditions which are conducive to its accumulation in the soil.

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RESPIRATION OF SOIL AND COMPOSITION OF SOIL AIR ON DRAINED PEAT-BOG SOILS

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Control of air-water regime in soil is one of the decisive factors in obtaining large crop yields on peat-bog soils. Air deficiency and excessive CO_2 content are often responsible for the poor growth of plants on such soils. It is important to know not only the total air content in peat-bogs, but also its qualitative composition and the intensity of the gas exchange.

Between 1955 and 1958 we observed the intensity of soil respiration and the composition of soil air on drained peat-bog soils of the Yakhrom floodplain (Moscow region).[1]

The following two soils were selected: the humus-peat-iron on a grass-woods peat (Profile 56) and the humus-peat-iron-carbonate on a thick sedge-hypnum peat (Profile 58).

A complete description of the chemical and hydro-physical properties of these soils and of the geomorphological conditions is given by Skrynnikova (11, 12). Both soils have a high ash content in their upper horizons (33%-35% in the 0-20 cm layer) and a high iron content (9%-15%).

The soils are situated in different locations. Profile 56 is located in the central part of the floodland with more drainage (drains 50 m apart) than Profile 58 which is located in the lower terrace part of the same floodland. Profile 56, therefore, has more favorable air-water conditions.

As can be seen in Table 1, all four years under study had quite different meteorological conditions: 1955 and 1957 were drier than 1956 and 1958; in 1955, May and June were cold and rainy, July and August — warm and with small amounts of precipitation; in 1956, June was warm with a moderate amount of precipitation, July and August were cold and rainy; in 1957, May was very warm, the second half of June and the first part of July were warm; in 1958, the third part of May was very warm and dry, the first and last of June were rather dry marked by a sharp temperature decrease, July and the first part of August were warm and had a moderate amount of precipitation; the rest of August and September were cold and rainy.

The soils under observation were fields of perennial grasses (foxtail, timothy, meadow, fescue, vetch) and on fallow field (Profile 58) with grass-hyphen peat.

In 1955 and 1956 the intensity of CO_2 evolved from the soil was determined by the "domiki" (3) method, and in 1957 and 1958 — by the flask method (5), replicated 4 to 5 times. Since the intensity of soil respiration varies considerably within each day-and-night period, all readings were taken at the same time (between 9 and 12 AM) two to three times a month. The following factors were determined each time: temperature of the air and soil at a depth of 5 cm; soil moisture in the 0-10, 10-20 and 20-30 cm layers; and the ground-water level. The plant roots in surface and subsoil were also measured.

The quantity of roots was determined by extracting three soil samples from 0-10, 10-20 and 20-30 cm depths of each plot. This was done by means of an iron form measuring 10 x 15 x 10 cm. The roots were thoroughly washed in a sieve (diameter of openings 0.25 mm), air-dried and then plant residues were picked by tweezers.

Table 2 shows that the quantity of perennial grass roots is very large in the 0-30 cm soil layer (up to 17 metric tons/ha). It is distributed over the peat-bog soil profile as follows: the 0-10 cm layer contains 80%-90% of all roots, the 10-20 cm layer — 5%-17%, and the 20-30 cm layer — 1.5%-5%.

Observations of soil respiration revealed that the CO_2 evolved under grasses was 1.5-2 times larger than under a fallow plot. The same phenomenon was observed on sod-podzolic soils. It shows how important is the part of the respiration of plant roots in producing the soil CO_2. The intensity of soil respiration varies during the growing season primarily because of the changes of soil temperature and moisture. The main role here is played by the temperature. This correlation is vividly shown by Figure 1. The soil respiration curves generally follow those of temperature. The lowest intensity of soil respiration

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[1] Academician I. V. Tyurin supervised this work. M. A. Shvabe participated in the field and laboratory investigations in 1956 and 1957; V. P. Ignatova participated in them in 1958.

Table 1

Average monthly temperatures and precipitation

Month	Average for year's service		1955		1956		1957		1958	
	Air temperature	Precipitation	Air temperature	Precipitation	Air temperature	Precipitation	Air temperature	Precipitation	Air temperature	Precipitation
May	11,2	60,2	10,5	94,7	10,5	88,4	13,7	31,4	12,5	49,4
June	16,7	67,7	14,6	67,8	19.8	54,0	14,6	76,7	14,4	85,0
July	17,4	95,7	17,8	44,3	15,4	104,3	18.5	42,9	17,5	39,8
August	16,2	76,3	17,4	32,7	14,7	120,2	16,4	81,2	15,3	94,3
September	10,9	53,0	13,3	40,2	8,2	26,2	12,0	54,8	8,9	47,8
	mean	sum	mean	sum	mean	sum	mean	sum	mean	sum
May-September	14,4	352	14,7	280	13,7	393	15	287	13,7	316

Note: Comma represents decimal point.

Table 2

Weight of perennial grass roots in the 0-30 cm soil layer

Profile No.	Units of measure	Depth, cm											
		0–10	10–20	20–30	0–30	0–10	10–20	20–30	0–30	0–10	10–20	20–30	0–30
		June 8				July 7				August 25-28			
		1955											
56	cntr/ha	Not det'd.				70,5	7,0	1,7	79,2	118,7	10,7	3,0	131,4
	%	"				89,2	8,8	2,0	100,0	89,6	8,0	2,4	100,0
58	cntr/ha	"				61,3	13,5	1,86	76,7	102,2	5,76	0,86	108,8
	%	"				79,8	17,6	2,6	100,0	93,1	5,3	1,6	100,0
		1956											
56	cntr/ha	90,5	18,5	4,68	113,7	112,8	15,6	13,1	141,5	151	16,8	7,31	175,1
	%	79,5	16,3	4,1	100,0	79,9	11,1	9,0	100,0	85,8	9,6	4,6	100,0
58	cntr/ha	75,5	9,8	2,5	87,9	111,1	8,75	5,70	125,3	112,1	17,8	5,0	134,9
	%	86,1	11,2	2,7	100,0	88,7	7,0	4,3	100,0	83,2	13,3	3,5	100,0

Note: Comma represents decimal point.

s observed at the end of April and beginning May. This period was characterized by a gh ground-water level, a high soil moisture d low temperature.

The intensity of soil respiration increased the end of May and in June because of a sig- ficant drop of the ground-water level, a wering of soil moisture and an increase of il temperature. For example, the ground- ter level dropped between the end of May d June 15, as follows: In 1956, Profile 56 om 50 to 83 cm; Profile 58 from 17 to 70 . In 1957, from 60 to 92 cm and from 31 75 cm, respectively. During all years the aximum readings of the intensity of soil respiration coincided with the most favorable moisture-temperature conditions — the lowest ground-water level and maximum soil temperature. For example, in 1957 the maximum intensity of the CO_2 evolved was recorded on July 30 when the ground-water level for Profiles 56 and 58 was 115 and 82 cm deep, respectively, and the soil temperature (19°C) and air content reached their highest point. The soil moisture was at that time down to the level of the minimum moisture capacity.

The intensity of the CO_2 evolved is related to the growth of plants. Usually, it was highest during the period of the maximum growth of grass before it was mowed.

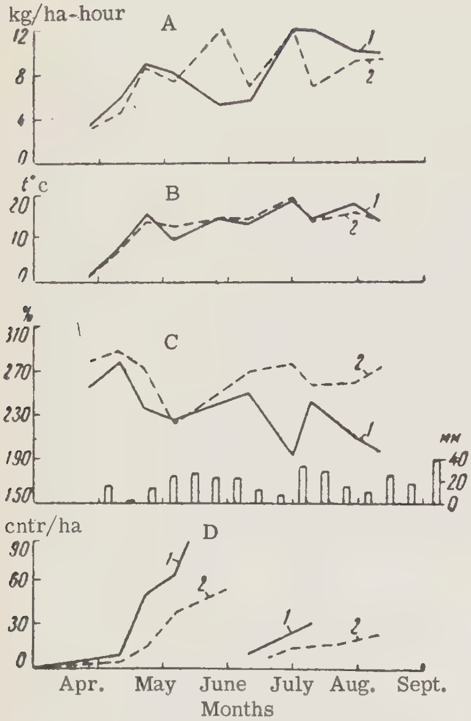

Fig. 1. - Effects of plant growth, temperature and soil moisture on the intensity of soil respiration. Grasses in 1957.

1 - Profile 56; 2 - Profile 58; A - soil respiration; B - soil temperature; C - soil moisture in the 0-20 cm layer and precipitation; D - weight of dry mass above the surface.

Table 3 provides a comparison between the intensity of soil respiration on grass-woods peat (Profile 56) and on grass-hypnum peat (Profile 58). In the former case, the CO_2 evolved was 10%-20% larger than in the latter. This can be explained by the differences in physicochemical properties of these peats and by the fact that the grass-woods peat has a better developed complex of the surface and subsoil roots of perennial grasses. Two annual mowings produced together the following yields for Profile 56 and Profile 58, respectively: in 1955 — 82 cntr/ha and 61 cntr/ha, in 1956 — 96 cntr/ha and 61 cntr/ha, in 1957 — 118 cntr/ha and 77 cntr/ha, in 1958 — 95 cntr/ha and 50 cntr/ha. The 0-30 cm layer of the grass-woods peat contained 15%-30% more grass roots than did the same layer of the grass-hypnum peat (Table 2).

Hydro-thermal changes during the growing season affect the intensity of soil respiration primarily because of the ensuing changes in the intensity of the following biological processes: activity of micro-organisms, growth and physiological activity of plant roots. The published works of Lupinovich, Golub (1), Rybalkina (10) and of others describe the effects of soil temperature and moisture and of bog drainage methods on the total quantity and and physiological composition of microorganisms, and on the development of the active soil microflora.

It should be noted that peat-bog soils liberate CO_2 two to three times more intensity than sod-podzolic soils. For instance, the respiration of peat-bog and sod-podzolic soils was recorded in 1955 as follows: under perennial grasses 9-11 kg/ha and 5-6 kg/ha per hour, on fallow plot 4-6 kg/ha and 2-3 kg/ha per hour, respectively. The high intensity of the CO_2 liberated by peat-bog soils creates favorable conditions for plants carbon nutrition.

The genesis of peat-bog soils and the air composition throughout their profile are related to the varying intensity of the CO_2 evolved at different depths. To investigate the latter problem, the intensity of gas exchange was measured at depths of 10, 20, 40 and 60 cm. The initial measurements were taken immediately after digging 40 x 40 cm pits of the required depth. They were then repeated several times a month. Table 4 gives the data of one of the readings (7 days after digging the holes). The same regularity was observed in the results of all other readings. It leads to the conclusion that under natural conditions the intensity of gas exchange decreases with depth.

Different soil layers have different intensity of gas exchange not only because of their individual physiochemical properties, but also because of the differences in soil temperature and moisture. Table 4 shows that soil temperatures and moisture change with depth (temperature decreases and moisture increases). This affects the intensity of production and the rate of diffusion of CO_2.

Content of CO_2 and O_2 in the Soil Air

The samples of soil air from the plots under observation were withdrawn by means of copper tubes, 4-6 mm in diameter, which were permanently installed at a depth of 10, 20, 30 and 60 cm. The method of their installation has been described by Matskevich (8).[2] The method of round-bottom flasks (7) was used to withdraw the air and to determine how much CO_2 and O_2 it contained. The CO_2 content in the soil air was determined two-to-three times a month along with the measuring of soil respiration.

Table 5 and Figure 2 present the data of CO_2 content in the soil air in 1957 and 1958. The CO_2 fluctuated greatly throughout the year, reaching the highest point during the summer months and sharply decreasing in all soil horizons in spring and fall.

Fluctuations in CO_2 content during the growing season are similar to fluctuations in the intensity of soil respiration associated with the intensity of biological processes. The latter are an effect of changes in hydro-thermal conditions. Available data show a correla-

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[2] This method is used to draw the air from large pores.

Table 3

Respiration of peat-bog soils (CO_2 liberated per kg/ha, per hour)

Profile No.	Plot											
		1955[a]										
		May 20	June 31	June 14	July 5	July 26	Aug. 26	Aug. 23	Sept. 6	Average		
56	Grs.	4,20	6,97	9,57	11,05	7,46	7,01	6,60	5,64	7,30		
58	Grs.	3,72	6,54	7,85	7,50	6,22	6,12	5,51	4,56	6,00		
"	Fallow	2,11	2,36	5,80	3,43	4,18	4,00	3,73	2,83	3,56		
		1956										
		June 5	June 15	June 22	July 5	July 17	Aug. 1	Aug. 15	Aug. 30	Sept. 7	Sept. 20	Average
56	Grs.	8,68	9,08	11,1	8,68	4,51	6,77	5,80	9,05	6,38	5,00	7,50
58	Grs.	5,96	5,84	10,3	8,45	7,81	9,60	3,98	7,50	6,40	2,94	6,87
"	Fallow	3,82	8,19	8,24	8,51	4,84	4,87	2,92	5,75	4,52	2,13	5,27
		1957										
		Apr 25	May 10	May 22	June 5	June 26	July 10	July 30	Aug. 8	Aug. 28	Sept. 10	Average
56	Grs.	3,46	6,00	9,05	8,15	5,30	5,58	12,2	12,1	10,10	9,88	8,18
58	Grs.	3,06	4,75	8,90	7,44	12,0	6,78	12,2	6,76	9,24	9,40	8,05
"	Fallow	1,35	1,63	3,42	3,34	5,78	5,85	6,10	5,65	5,90	5,10	4,40
		1958										
		May 5	May 30	June 12	June 23	July 15	July 30	Aug. 16	Aug. 25	Sept. 10	Sept. 22	Average
56	Grs.	1,57	8,25	8,40	7,65	10,7	10,3	6,94	8,40	6,78	4,06	7,30
58	Grs.	0,87	4,02	8,43	10,0	9,60	7,65	6,66	5,62	4,45	2,61	5,91
"	Fallow	0,41	3,86	5,55	4,22	2,06	4,02	3,96	1,60	3,32	1,06	3,06

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[a] In 1955 readings were taken eight times.

Note: Comma represents decimal point.

Table 4

The intensity of soil respiration at various depths

Depth, cm	Profile 56			Profile 58		
	Soil temperature	Soil moisture % of volume	CO_2 evolved per kg/ha, per hour	Soil temperature	Soil moisture % of volume	CO_2 evolved per kg/ha per hour
On surface	16,0	47,7	6,77	19.5	54,0	7,93
10	—	—	—	18,2	67,2	6,76
20	13,5	58,4	5,04	17,7	65,5	4,30
40	12,0	63,7	3,0	16,5	87,5	3,51
60	11,0	75,0	2,65	15,0	90,0	2,33

Note: Comma represents decimal point.

on between the CO_2 content, on the one hand, d the soil temperature and moisture, on the her. In June, as compared to May, the CO_2 ntent is on the increase. This is caused by decrease in the soil moisture and an inease in the soil temperature. In 1957 and 58 the maximum temperature was recorded ring the July-August period which coincided th the increased concentration of CO_2 in the soil air.

The CO_2 content in the upper layers of the three plots under observation was many times smaller than in the layers below. Yet, it is the 0-10 cm layer that has the bulk of all plant roots, contains twice as many bacteria as the 10-20 cm layer, and, therefore, produces more CO_2. The CO_2 content, however,

Table 5

CO_2 content in the air of peat-bog soil, expressed in volume percents at O°C and 760 mm Hg in 1957

Date of reading	Profile 56, grasses				Profile 58,grasses			Profile 58, fallow		
	Depth, cm									
	10	20	30	60	10	20	30	10	20	30
June 5	0,357	1,99	3,29	—	—	—	—	0,349	0,655	—
June 26	0,820	1,99	2,67	4,10	0,849	3,90	7,85	0,222	0,576	0,910
July 10	0,715	2,30	3,18	4,84	0,842	2,53	5,88	0,204	0,415	0,790
July 30	0,506	1,43	2,17	4,83	1,88	5,22	9,92	0,283	0,882	1,66
Aug. 8	0,910	2,54	3,67	5,82	2,29	7,00	8,55	0,234	0,720	1,10
Aug. 28	0,905	1,99	2,76	5,78	1,80	5,27	10,12	0,238	0,551	1,37
Sept. 10	0,830	2,02	2,92	6,49	1,75	2,85	12,2	0,287	0,515	1,37
Nov. 1	0,413	1,04	1,85	3,28	—	1,21	—	0,068	0,238	0,528
Nov. 21	0,502	0,730	1,07	2,06	—	—	—	0,065	0,184	—

Note: Comma represents decimal point.

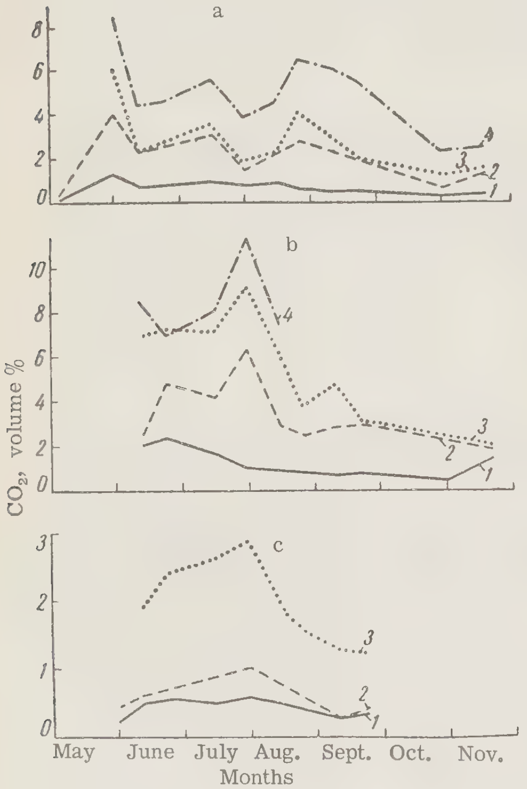

Fig. 2. - Changes in the CO_2 content in the soil air in 1958.

1 - 10 cm; 2 - 20; 3 - 30; 4 - 60 cm; A - Profile 56; B - Profile 58 grass; C - Profile 58, fallow.

consistently increases with depth. This phenomenon can be explained by the fact that there is no proportional relationship between the rate of CO_2 formation and diffusion in different soil layers.

The fallow plot contained at all times and depths considerably less CO_2 than did the perennial grass plots. Thus, for instance, between July and September of 1958 the mean CO_2 content in the soil air of the fallow plot was: at a depth of 10 cm – 0.5% of the total volume, at a depth of 20 cm – 0.7% of the total volume, at a depth of 30 cm, 1.85% of the total volume. At the same depths the soil air from under grasses contained the following portions of CO_2, respectively: 1.33%, 3.82%, and 6.2% of the total volume. This difference is attributable to the fact that the plant roots respiration increases the production of CO_2.

The grass-hypnum peat (Profile 58) contained considerably more CO_2 than the grass-woods peat (Profile 56).

The higher CO_2 content in the grass-hypnum peat (Table 6) is related to the higher degree of its moisture and, thus, slower rate of gas exchange. In 1957 the mean soil moisture was 243% for Profile 56 and 264% for Profile 58 (absolute dry soil). In 1958 the readings were 221% and 253%, respectively. In 1957 the ground-water level was 93 cm under the grass-woods peat and 64 cm under the grass-hypnum peat. In 1958 the depths were 87 and 59 cm, respectively.

The oxygen content during growing season changed considerably, inversely proportional to the CO_2 content. An increase in the CO_2 concentration consistently led to a decrease in the oxygen content of the soil air (Table 7). The minimum oxygen content recorded at different depths was as follows: 10 cm deep – 19% of volume, 20 cm deep – 16.5% of volume, 30 cm deep – 14.2% of volume, 60 cm deep – 12%-14% of volume. The total percentage of CO_2 and O_2 was not always and not at all depths found to be 21%, i. e., equal to the (sum of CO_2 and O_2 in the atmospheric air. At depths of 30 and 60 cm this sum exceeded 21%. We are inclined to explain the CO_2 concentration in these hori-

Table 6

Mean content of CO_2 in the soil air from June Sept. expressed in volume %

Depth, cm	1957		1958	
	Profiles		Profiles	
	56	58	56	58
10	0,72	1,57	0,75	1,33
20	2,03	4,45	2,60	3,82
30	2,95	9,05	3,06	6,20
60	5,28	—	5,35	8,30

Note: Comma represents decimal point.

Table 7

Content of CO_2 and O_2 in the soil air, in volume % at 0°C, and 760 mm Hg in 1958

Profile No.	Depth, cm	June 12		July 1		July 30		Aug. 25		Sept. 22	
		CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2
56	10	0,709	—	0,982	19,4	0,777	20,2	0,645	20,12	0,555	19, 4
	20	2,32	—	4,96	16,55	1,47	19,4	2,79	17,9	1,93	—
	30	2,35	—	5,45	15,55	1,88	—	3,35	18,3	2,09	18,9
	60	4,45	—	6,92	14,3	3,91	17,22	6,50	14,4	5,50	—
58	10	2,07	19,1	1,57	19,0	1,04	19,4	0,852	20,0	0,800	20,1
	20	2,52	18,5	5,19	17,0	6,27	15,5	2,55	18,3	3,05	17,8
	30	6,95	15,0	7,48	14,5	9,20	14,9	3,75	18,1	3,17	18,20
	50	8,45	14,7	7,45	14,25	11,4	12,0	water		water	

Note: Comma represents decimal point.

ons in terms of not only biological but also emical processes (the peats under observa-on contained large quantities of carbonates). t depths of 10 and 20 cm for Profile 56 and) cm for Profile 58 the sum of CO_2 and O_2 ontents in the soil air was close to 21%. This dicates that under the conditions of biological ocesses the exchange of CO_2 and O_2 is equiva-nt.

It should be noted that the soil air of drained at-bogs has a very high concentration fo CO_2 aching at a depth of 10 cm 1%-2% and below at 4%-11% of volume. The CO_2 content in d-podzolic chernozem and meadow-cinna-on-brown soils is considerably less. It does t exceed 1% in the upper 50 cm-deep layer , 8, 9). The high concentration of CO_2 in the r of peat-bog soils may become toxic for e development of micro-organisms and rmal activity of plants. According to Lyunde-rd (2), the limit of the CO_2 concentration is -2%. After that it becomes harmful to agri-ltural crops.

Poor development of plants and nitrogen de-iency in some peat-bog soils could be prob-ly attributed to the CO_2 toxic properties.

Therefore, it is essential to improve the aeration of peat-bog soils under agricultural crops.

As we have already pointed out, there is a definite correlation between the intensity of respiration and moisture of a soil. Under practical conditions in the field it is, however, difficult to determine the exact degree of the soil moisture. Thus, in order to observe the moisture effects upon the biological activity of peat-bog soils, we conducted a laboratory experiment with two horizons (0-20 and 20-40 cm) of grass-woods and grass-hypnum peats. In watering these peats we were guided by the following three contrasting moisture factors: the wilting moisture, the minimum moisture capacity, and the 95% of the total moisture capacity. The biological activity was determined by the intensity of the CO_2 liberated with the flask method (5). Table 8 shows that the optimal biological soil activity (by CO_2 liberated) was reached at a moisture corresponding to the minimum moisture capacity. An increase of moisture from the minimum moisture capacity to that of 95% of the total moisture capacity did not affect very much the intensity of the CO_2 evolved. A sharp decline of biological activity was observed when the level of wilting moisture was reached.

Conclusions

1. Investigations of drained peat-bog soils have established a correlation between the soil respiration intensity and CO_2 content, on the one hand, and the soil temperature and moisture, the ground-water level, the development of root and above ground parts of plants, on the other hand. The maximum soil respiration intensity and the CO_2 content was observed at the time of the increased temperature and when the soil moisture corresponds to the minimum capacity.

Table 8

Effect of peat-bog soil moisture on the biological activity

Profile No.	Depth, cm	Liberation of CO_2 in mg per 100 g of absolutely dry soil, per hour		
		Wilting moisture	Minimum moisture capacity	95% of full moisture capacity
56	0—20	1,42	2,50	2,33
	20—40	2,35	4,52	4,82
58	0—20	1,63	2,77	2,35

Note: Comma represents decimal point.

2. The Bulk of the perennial grass roots is concentrated in the 0-10 cm layer of drained peat-bog soils.

3. The soil respiration intensity and the CO_2 content are considerably higher under perennial grasses, as compared to a fallow plot.

4. The gas exchange intensity is 1.5-2.5 times less in the lower layers of drained peat-bog soils, as compared to their upper layers.

5. The CO_2 content in the air of drained peat-bog soils under grass may reach a high percentage (at a depth of 10 cm up to 1%-2% of volume, at greater depths up to 4%-11% of volume). This indicates a need for measures to improve the aeration of such soils.

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ATER PERMEABILITY OF CERTAIN SOD-PODZOLIC SOILS

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Water permeability is an important factor in termining moisture-aeration conditions of il, which, in turn, greatly influence the rection of physical, physicochemical and biogical processes.

Doyarenko (4), Karchinskiy (7), Yegorov (5), enevol'skiy (1) and others have shown by their vestigations that the water permeability of d-podzolic soils as a whole, as well as of its dividual genetic layers, depends on the texre and is closely related to its structure and nsistence.

According to Kachinskiy (7), individual horins of the medium-podzolic fine clay loam dif from each other in regard to their water rmeability as follows: a) the podzolic horin has the best water permeability; b) water rmeability of the humic-accumulating horin is four to six times lower; c) water perability of B_1 horizon is 70-80 times lower n that of A_2 horizon; d) water permeability B_2 horizon is hundreds and thousands of es lower than that of A_2 horizon; e) water rmeability of B_3 horizon is considerably bet than that of B_2 horizon.

A higher degree of water permeability of horizon, as compared to A_p, has been also ed by Yegorov (5) who studied podzolic ess-like clay loam" at the Engel'gardtovya experimental station. However, a few lished experimental data show the opposite clusions. Thus, for instance, Shchepanovy (14), who studied "podzolic clay loams" at the Engel'gardtovskaya experimental tion, refers to an experiment for water perability of a 20-cm-thick soil column. The meability during a three-hour period was as ows: A_1 horizon — 44 mm, A_2 horizon — 16 , B_1 horizon — 3 mm.

Benevol'skiy (1), who investigated mediumzolic fine clay loams underlain with a loess clay loam, found that A_1 horizon had a conrably better water permeability than A_2 zon.

Contradictory opinions like those mentioned viously show the complexity and insufficient y of this problem.

Likewise, it is not quite clear how the sub loosening affects the water permeability of the podzolic horizon and soil, as a whole. Doyarenko (4) thinks that the water permeability of the podzolic horizon is made possible by pores which are retained by soil only under natural conditions. Hence, according to him, the loosening of soil lessens its water permeability. During one of his experiments a 4.4 cm deep loosening of a podzolic horizon decreased its water permeability 14 times. The same phenomenon was noted by Kachinskiy (7, 8), Zakharov (6), Chizhevskiy and Bogomolov (13), and Pannikov (9). It is usually attributed to the destruction of the natural consistence and structure of the podzolic horizon. But, as we have said before, the podzolic horizon does not always have an adequate degree of water permeability under the natural structural conditions. It would be wrong to over-estimate the part played by cracks and worm-holes. In any case, there is a vast number of medium clay loams and coarse clay loams, which have a sandy, often cemented together, podzolic horizon (and also a cemented upper part of the illuvial horizon). Even in the case of soils with a finer texture cracks may play a significant part mostly during summer when the water permeability of the podzolic horison is no longer of such a great importance.

We should also mention Benevol'skiy (1), who, as a result of his observations, came to the conclusion that the loosening of soil leads to an increased water permeability in the podzolic horizon. Thus, in one case the water permeability of a podzolic horizon, loosened three months before, was higher than originally. Therefore, as Benevol'skiy has pointed out, a podzolic horizon serves as a water-barrier. Should it be loosened, all of the soil water-aeration conditions change.

Published data on water permeability of sod-podzolic soils is still sketchy. As a result, it is impossible to complete the picture of how this factor changes from one to another genus of sod-podzolic and podzolic soils.

This article gives descriptions of physical properties of certain soils of the Leningrad region. We have studied several typical sod-podzolic and podzolic-gley soil profiles, mostly on locations of experiments conducted by the Leningrad Section of the VIUAA between 1946 and 1955. Our task was to study the physical properties of the entire soil profile, down to the parent

Table 1

Physical characteristics of soils

Soil	Horizon	Depth, cm	Percent of particles <0.01 mm in diameter	Particle density	Bulk density, g/cm³	Total porosity, % of volume	Resistance to pressure by a hard body, kg/cm² (Revyakin's method)	Max. hygroscopicity, % of absolute dry soil (Nikolayev's method)	Water intake rate, mm/min (mean for 60 minutes) [a]	moisture-capacity full	moisture-capacity capillary	Moist. at the time of investigation
										% on absolute dry basis		
Sod-podzolic coarse clay loam on gravel sandy loam	A_p	0—25	24,25	2,56	1,38	46	18	3,21	5,5	30,9	27,1	12,2
	A_2	28—40	23,50	2,65	1,49	44	22	2,53	1,0	24,4	24,3	11,9
	B_2	70—80	6,75	2,63	1,55	41	34	1,91	22,8	22,8	21,2	6,6
Sod-podzolic very fine sand on gleyed sandy loam	A_p	0—18	9,25	2,62	1,40	47	8	1,00	4,3	29,1	27,6	12,6
	A_2	20—30	9,00	2,61	1,55	31	38	0,81	0,1	15,4	13,7	11,8
	B	32—42	17,75	2,65	1,81	42	21	3,13	2,5	27,8	24,6	8,2
Sod-podzolic coarse clay loam on non-carbonate morainic clay loam	A_p	0—20	24,75	2,54	1,36	46	38	1,97	1,6	38,1	30,0	10,4
	A_2B_1	24—37	27,25	2,63	1,67	37	>40	—	0,4	30,1	25,2	6,1
	B_1	37—45	37,25	2,65	1,67	37	40	4,39	0,2	17,9	15,6	11,9
	B_2	60—70	39,00	2,68	1,77	34	37	3,46	0,1	18,3	17,5	12,8
	C	80—90	39,25	—	—	—	26	4,64	—	—	—	—

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[a] Without corrections for moisture and lateral flow.

Note: Comma represents decimal point.

Table 2

Physical characteristics of soils

Soil	Horizon	Depth, cm	Percent of particles <0.01 mm in diameter	Particle density	Bulk density, g/cm³	Total porosity, % of volume	Resistance to pressure by a hard body, kg/cm² (Revyakin's method)	Max. hygroscopicity, % of absolute dry soil (Nikolayev's method)	Water intake rate, mm/min (mean for 60 minutes) [a]	moisture-capacity full	moisture-capacity capillary	Moist. at the time of investigation
										%on absolute dry basis		
Sod-podzolic silt coarse-clay loam on non-carbonate eroded clay loam	A_p	0–20	29,25	2,55	1,44	44	13	3,11	2,3	30,0	25,0	25,0
	A_2	20–27	27,25	2,58	1,60	38	21	2,65	2,8	21,5	18,8	17,4
	B_1	30–40	25,25	2,65	1,70	36	27	1,72	6,8	18,0	14,6	15,8
	B_2	50–60	36,50	2,62	1,74	30	40	2,99	1,5	15,3	13,3	13,1
	C	100–110	30,50	2,75	1,83	32	31	2,22		14,2	13,2	14,1
Sod-podzolic silt clay loam on non-carbonate clay loam	A_p	0–20	38,00	2,58	1,38	48	22	3,36	2,1	32,0	26,6	20,6
	A_2	25–40	38,50	2,60	1,55	40	32	2,43	1,0	21,80	20,1	15,7
	B	40–60	45,25	2,65	1,68	37	40	3,44	2,2	19,9	17,7	14,2
Sod-slight-podzolic fine clay loam on carbonate morainic clay loam	A_p	0–18	42,50	2,55	1,45	43	40	3,69	1,7	34,5	28,9	8,5
	A_2/B	18–30	38,75	2,57	1,66	35	>40	2,53	1,2	30,40	—	10,5
	B	30–60	39,25	2,64	1,83	31	>40	3,00	0,2	19,8	14,1	11,3
	B/C	60–90	46,50	2,66	1,69	36	31	5,61	1,0	26,0	21,4	15,0

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[a] Without corrections for moisture and lateral flow.

Note: Comma represents decimal point.

Table 3

Physical characteristics of soils

Soil	Horizon	Depth, cm	Percent of particles <0,01 mm in diameter	Particle density	Bulk density, g/cm³	Total porosity, % of volume	Resistance to pressure by a hard body, kg/cm² (Revyakin's method)	Max. hygroscopicity, % of absolute dry soil (Nikolayev's method)	Water intake rate, mm/min. (mean for 60 minutes) a	moisture-capacity: full	moisture-capacity: capillary	Moist. at the time of investigation
										% on absolute dry basis		
Sod-slight-podzolic fine clay loam on carbonate morainic clay loam	Ap	—	43,25	2,56	1,29	50	35	—	2,0	31,8	25,4	15,3
	A_2,B	—	—	2,60	1,62	38	>40	—	0,9	28,8	24,1	10,5
	B	—	—	2,64	1,57	41	>40	—	1,5	25,1	19,7	15,6
Sod-humic-carbonate leached clay	Ap	0—25	52,00	2,63	1,37	48	>40	—	2,5	31,2	25,4	16,2
	B_1	25—35	60,25	2,70	1,34	50	>40	—	3,8	28,8	24,1	19,0
	B_2	60—70	49,00	2,73	1,46	46		—	5,0	25,1	19,7	13,7
	C	85—90	51,25	2,72	1,71	37		—	2,5	22,0	19,0	16,0
Sod-podzolic gley-clay loam on clay lens	Ap	0—18	64,25	2,54	1,29	49	23	6,57	4,0	48,4	—	28,2
	A_2	20—30	66,25	2,66	1,55	42	>40	6,46	<0,1	36,8	—	19,6
	B	40—55	73,00	2,80	1,62	42	>40	8,66	<0,1	—	—	20,7

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[a] Without corrections for moisture and lateral flow.

Note: Comma represents decimal point.

Table 4

Particle size analysis and water permeability[a] of sod podzolic soils and their genetic horizons

Soil	Horizon	Depth, cm	Percentages of particle diameters (Kachinskiy's method)					Water intake, mm/min. hours				Moisture, % of absolutely dry soil before determining intake rate
			1—0,25	0,25—0,01	0,01—0,005	0,005—0,001	<0,00,1	1	2	3	4	
Sod-podzolic sandy loam on non-carbonate morainic clay loam	A_p	0—23	18,31	62,24	8,15	7,85	3,45	2,80	2,60	1,80	1,60	14,1
	A_2	26—28	25,24	57,91	6,65	6,70	3,50	1,20	1,10	1,20	1,00	9,2
	A_2B_1	45—50	21,85	47,55	5,90	11,70	13,00	1,00	0,75	0,72	0,88	9,7
	B_2	85—90	21,10	48,75	5,65	9,80	14,70	1,00	0,94	0,97	1,04	11,1
Sod-podzolic coarse clay loam on morainic clay	A_p	0—20	11,94	67,01	7,80	10,65	2,60	0,58	0,45	0,36	0,35	18,6
	A_2	25—35	10,70	63,55	8,05	10,15	7,55	2,00	1,30	1,14	1,04	9,9
	B_1	50—60	18,95	52,30	7,00	11,25	10,50	0,73	0,27	0,28	0,30	10,9
	B_2	115—125	18,60	54,85	7,30	10,40	8,85	0,08	0,06	0,03	0,03	15,6
Sod-podzolic clay loam on carbonate clay loam	A_p	0—25	11,61	50,54	11,50	16,35	10,00	1,18	0,65	0,42	0,38	19,7
	A_2	28—32	9,74	54,86	10,40	16,25	8,75	0,19	0,16	0,13	0,09	14,3
	B_1	46—60	9,64	48,11	9,50	19,75	13,00	1,98	1,36	1,14	1,03	19,9
Sod-podzolic coarse clay loam on morainic clay loam	A_p	0—18	15,70	55,60	9,40	12,05	7,25	2,10	0,87	0,82	0,30	19,8
	A_2	20—28	20,53	51,12	6,85	12,90	8,60	2,00	1,25	0,81	0,67	5,3
	B_1	45—56	15,90	50,65	10,60	13,25	9,60	0,86	0,58	0,43	0,22	13,9
Sod-podzolic gley clay on clay lens	A_p	0—20	9,93	32,32	11,95	32,90	12,90	3,50	3,30	2,60	2,10	27,1
	A_2	20—27	4,28	42,47	7,90	31,75	13,60	1,62	0,84	0,52	0,33	18,4
	B_1	45—50	0,68	27,22	10,15	42,15	19,80	0,09	0,07	0,06	0,02	21,6

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[a] Water permeability was determined by cylinders, 5 cm in diameter and 15 cm tall. They were installed in genetic horizons under study. The lower edge was pressed 1.5 cm into soil. Replication — 4 to 8 times. Water was added one hour after measuring absorbed water. When intake rate was faster than 135 mm/hour, water was added along with the absorption of the water column.

Note: Comma represents decimal point.

material. Data of this type for the Northwestern zone are scarce and limited chiefly to virgin lands and forests. Pigulevskiy has also given a thorough description of old plowed soils, but, unfortunately, he was concerned only with the upper (A_p and A_2) sod-podzolic horizons rather than with the entire profile. And it is the entire profile which must be studied in order to solve problems of the control over the soil water-aeration conditions.

During the summer of 1955 we have studied the physical properties of the following soil profiles:

sod-podzolic coarse clay loam on gravel sandy loam; sod-podzolic very fine sand loam on gley sandy loam; sod-podzolic coarse clay loam on non-carbonate moraine clay loam; sod-podzolic silty coarse clay loam on non-carbonate eroded clay loam; sod-slight-podzolic fine clay loam on carbonate morainic clay loam; sod-humic-carbonate leached clay, sod-podzolic-gley clay on clay lens.

The results of the investigations of several physical factors are given in Tables 1, 2 and 3.

The differences between various soils and their individual layers in regard to water permeability were so pronounced that even while conducting only short (60 minutes) observations and using somewhat incomplete methods,[1] we were able to establish certain distinctive regularities.

The soils can be divided into three groups in accordance with their specific water intake properties:

1. Soils with the lowest water intake rate in the podzolic horizon; this rate increases in the illuvial horizon which has an intake factor approaching that of the plowed layer; to this group belong not only fine clay loam but also several sandy loamy and coarse clay loam podzolic soils (Profiles 1, 2 and 5) which have a definite compaction in their podzolic horizons. An improvement of the physical properties of the podzolic horizon of the soil group should increase the water permeability of the entire soil profile. This would be especially important for clay and fine clay loam varieties.

2. The rate of water intake decreases with depth (Profiles 3 and 9); this is especially true of podzolic-gley soils; an improvement of the physical properties of their podzolic-gleyed horizon does not increase water permeability of the entire soil profile; thus, favorable aera-

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[1] To determine water permeability we employed, with a two- to four-fold replication, bottomless containers 20 cm in diameter. The containers were installed in the genetic horizons under study. The lower edge of containers was pressed 2 cm deep into the soil. They were filled with 1 liter of water giving a 31.8 mm water column. As soon as 30 mm were absorbed (under varying pressure), the vessels received additional 1 liter of water each. The absorbed water was measured by a removable mm-ruler attached to the wall inside each vessel.

Table 5

Water intake in relation to cultivation depth; sod-podzolic clay on clay lens. Intake rate in mm/minute.

Horizon	Time of readings	When readings were taken	Intake rate after			
			1st	2nd	3rd	4th
			Liters			
A_p	July 20-23, 1954	After cultivation	96,00	64,00	27,00	12,30
A_p	"	45 days after cultivation	128,00	14,10	14,00	4,00
A_2	"	Without loosening	2,67	0,97	0,60	0,41
"	"	13 months after loosening	14,90	6,60	3,80	3,30
"	"	Without loosening	0,06	—	—	—
"	"	45 days after loosening	31,80	31,80	31,80	27,70
"	"	13 months after loosening	7,80	8,20	4,00	2,50
"	September 28	Without loosening	0,26	—	—	—
"	"	105 days after loosening	28,50	18,90	14,70	8,20
"	June 18, 1955	Without loosening	2,90	—	—	—
"	"	12 months after loosening	14,40	3,30	—	—

Remarks: Water intake was determined by containers, 20 cm in diameter, on laboratory-field experiment plots and on other special plots.

Note: Comma represents decimal point.

Table 6

Coefficient of permeability for loosened and non-loosened podzolic horizons

Cultivation and the time of determinations	Coefficient of permeability, mm/min.					
	Replication					
	1	2	3	4	5	6
Without loosening	0,01	0,06	0,01	0,00	0,06	0,06
4 months after loosening	1,14	2,11	1,20	1,92	6,05	0,75

Remarks: Permeability coefficients were determined as the mean for the first 120 minutes of observation.

Note: Comma represents decimal point.

Table 7

Changes of bulk density in relation to cultivation depth

Cultivation treatments	Depth, cm	Date of observation				
		Before spring cultivation, May 31, 1954	June 30	July 22	Oct. 7	Before spring cultivation, June 18, 1955
Autumn— plowed-layer depth;	2—12	1,28	1,00	1,00	1,13	1,08
respaded in spring	20—27	1,54	1,49	1,52	1,56	1,52
Autumn —plowed-layer depth;	2—12	1,21	1,00	0,98	1,22	1,04
respaded in spring with loosening of podzolic horizon	20—27	1,57	1,21	1,26	1,51	1,40
Autumn —with loosening of podzolic horizon;	2—12	1,18	0,99	0,97	1,15	1,04
respaded in spring	20—27	1,37	1,29	1,38	1,44	1,37

Note: Comma represents decimal point.

on can be created only by draining.

3. Soils with change in texture and con- stence in profile that account for water per- eability increase with depth.

This group of soils is more likely to have tter water-aeration conditions, especially ien subject to periodically excessive mois- re.

Our data pertaining to the varying water per- eability of sod-podzolic soils are corrabora- d by other studies, in the course of which ob- rvations lasted longer than one hour (Table .

The data provided by Table 4 show that the tterns related to the rate of water intake and corded by us during our 60-minute periods evailed during the following three hours of servation.

The physical factors, shown on Tables 1, 2, 3 and 4, do not permit the establishing of a correlation between them and the water permeability values. This confirms the opinion that water permeability is the expression of a very diversified and intricate complex of various soil properties. It is quite obvious that soils with different physical properties must react differently to the deep soil loosening.

Sod-podzolic-gley clay loam (Profile 9) had the following characteristic factors of the water intake rate by its genetic horizons: A_p — 4.0 mm/min; A_2 — <0.1 mm/min; B — <0.1 mm/ min.

This soil has practically no permeability in its horizon B, as was determined by means of Pigulevskiy's device (10). The permeability coefficient (in mm/minute) was expressed as follows: A_p — 0.460; A_2 — 0.058; B — <0.001.

Samples from B horizon, tested for their permeability, were not permeable even to one mm^3 of water during a period of one month.

Thus, in this soil the permeability coefficient for the podzolic horizon is higher than for B horizon, but almost eight times lower than for horizon A_p.

A deep soil loosening resulted in an increase of the intake rate of the podzolic-gley horizon (Table 5). Thus, for instance, the intake rate for the podzolic-gley horizon of an experimental plot was, 45 days after cultivation,[2] as follows: loosened soil — 31.8-27.7 mm/minute; non-loosened soil — 0.06 mm/minute. As has been established 13 months later, the increased intake rate of the loosened soil remained. The difference in the absorption rate was evident not only during the intake of the first liter of water but throughout the entire experiment.

Concurrently with the foregoing outlined field tests for intake rates, we were using Pigulevskiy's (10) device to determine the permeability coefficients. For this we obtained soil samples in paraffin "jackets." It should be noted that prior to this time (September) the soil had been excessively wet during July and August and there had been a long period of "flooding" of the loosened plowed layer. The established permeability coefficients are given on Table 6.

Consequently, four months after loosening the soil the permeability of the loosened podzolic-gley horizon proved to be higher than that of A_2 horizon, which was not loosened.

Of course, these data are not sufficient to draw general conclusions concerning the effects of deep loosening on water permeability of different sod-podzolic soils under varying conditions of their cultivation. However, we can definitely say that the concept of negative effects of loosening does not apply to all sod-podzolic soils. It is, of course, true that in some cases deep loosening leads to a very excessive wet cultivated layer. But this is caused not by a decrease in water permeability of the podzolic horizon but by the poor permeability of the lower, non-loosened, soil layers. In such cases it is actually necessary, as has been pointed out by Rassel (11), to eliminate the excessive soil moisture at the time of deep loosening by draining and other methods.

Soil clods of different sizes are formed when the podzolic horizon is being loosened by subsoil plows and plows with deep-cutting shares or by plows without mold-boards. Permeability and intake rate of such soil clods are similar to a certain degree to the water permeability of the non-loosened soil horizon.

The fact that the water penetrates very slowly inside such lumps and clods because of the dense compaction — is one of the peculiar aspects of studying the sod-podzolic-gley soils. As has been noted previously, these clods are formed during the cultivation, especially the loosening, of the podzolic-gley horizon. Surface wetting without deep water penetration protects such soil lumps from destruction, as has been noted on several occasions by Kachinskiy (7). This fact is responsible for the high (up to 80% in this soil) content of the so-called "water-stability of macro-aggregates" which can be determined by any one of several methods (for instance, by Savvinov's method which calls for initial capillary saturation of such aggregates).

Apparently it is, at least to a certain degree because of the relative stability of the clods that the compaction of a loosened horizon is slow and its increased porosity lasts rather lon While the non-capillary spaces of loosened A_2/I horizon are being filled with the gravitational moisture, this horizon is also receiving partic from the plowed layer. These particles become lodged in spaces between soil aggregates of A_2/ B_1 horizon. Later, as the compaction of the loosened podzolic layer continues, there emerges a new pattern of the interconnections among soil particles in A_2/B_1 horizon. This pattern is different from the original natural one.

If we assume that a mechanical effect change the pattern between the soil particle in the horizons below the plowed layer, then it would be logical to expect that after drying up these horizons should have different crack patterns. This was confirmed during a field-laboratory experiment in 1953 (Table 7) by the obtained data pertaining to bulk density.

Table 7 shows that during the dry summer of 1955 a decrease of bulk density of the horizon below the plowed layer was recorded in all experimental treatments (observations were taken between October 7, 1954 and June 18, 1955). This decrease was more pronounced in the plots which had been subjected to a deep soil-loosening. While drying up, the loosened podzolic horizon produced smaller soil clods (it developed more cracks of small sizes) but the non-loosened podzolic horizon became divided by large cracks into major soil clods.

The increased water permeability remains at least until the cracks close up under the effect of the increasing soil moisture. All such changes are, of course, closely related to, and determined by, the physical and physico-chemical soil properties.

Conclusions

1. A study of several sod-podzolic soils showed that they can be divided into the following three groups with respect to the water-intake properties of their genetic horizons:

a) soils in which the podzolic horizon has th slowest intake rate; b) soils in which the intake rate decreases with depth; c) soils in which the intake rate increases with depth.

2. A subsoil loosening of the sod-podzolic-

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[2] On the plots of the laboratory-field experiments soil was treated by hand. The plowed layer was first removed, the podzolic-illuvial horizon was then loosened by spade, and, finally, the plots were covered again by the plowed layer soil. The size of plots for each treatment was 3 m^2. There was a 4 to 8-fold replication. An 8 to 12-fold replication was used when the permeability and intake rate were determined.

eyed clay led to a stable increase in the ter permeability of the loosened horizon.

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AN ERRONEOUS THEORY OF SOIL MOISTURE MOVEMENT

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For the last ten years there has been in existence a theory of soil moisture movement based on an erroneous concept of the equilibrium between the liquid and gas phases in the cases when the shape of the boundary surface, the thickness of the liquid layer next to gas, and the concentration of dissolved compounds vary (10).

The basic premise of this theory stems from a denial of the validity of even the qualitative aspect of the Thomson formula for vapor pressure above curvilinear surfaces of the liquid-gas boundary. Starting from this assumption, the author of this theory came to the conclusion that the isothermic distillation through a gas medium must occur in the direction from concave to convex menisci. In spite of the fact that this conclusion directly implies the possibility of perpetual motion (and thus contradicts the principles of thermo-dynamics), it has confused and led into error some researches (5) and writes of popular scientific literature (9).

It is for these reasons that we deam necessary to present in a brief form the problem of equilibrium between the film and wedge moisture in soil on the one hand, and the vapor contained in the liquid-free pores, on the other.

Our presentation has two objectives: 1) to show the actual conditions of equilibrium between the condensed and vapor moistures in soils, and 2) to show specific erronious concepts which have led O. V. Shapovalova to her fallacious theory on soil moisture movement.

For our purpose it would be more convenient to consider the Thomson formula not in its usual form when a correlation of vapor pressure above two surfaces is related to the curvature of the boundary between them, but as it applies to the correlation of vapor pressure and thermodynamic factor changes characteristic for adjoining phases.

An equilibrium between two such adjoining phases can exist only when their temperatures and chemical potentials are equal:

$$\mu_v = \mu_l, \quad T_v = T_l. \qquad (1)$$

The symbols "v" and "l" stand for vapor and liquid, respectively.

For the general case the chemical potential differential can be expressed as follows (4):

$$d\mu = - sdT + vdp + du, \qquad (2)$$

assuming that "s" is entropy; "v" – volume; "u" — energy related to the gravitation field; and assuming that all these factors pertain to one molecule.

If we con sider this system when the temperature of the liquid and vapor phases is constant and the boundary surfaces are on the same level, i. e., when the gravitation field potentials are equal, we can change (2) to read as follows:

$$d\mu = vdp. \qquad (3)$$

When an equilibrium is maintained (1), a change of the chemical potential in one phase must be concurrent with an exactly same change in the other phase. It follows that:

$$d\mu_l = d\mu_v. \qquad (4)$$

By using our expression (3) for the factors $d\mu_l$ and $d\mu_v$, we can say that:

$$d\mu_l = v_l dp_l,$$
$$d\mu_v = v_v dp_v,$$

and, if we take into account condition (4), that:

$$v_l dp_l = v_v dp_v. \qquad (5)$$

The vapor volume of one molecule can be expressed as follows:

$$v_v = \frac{V_v}{N}, \qquad (6)$$

where N is the number of molecules in a gam-molecule, and V_v is the volume occupied by a gram-molecule.

Since $p_v V_v = RT$, instead of (6), we can have:

$$V_v = \frac{RT}{Np_v} \qquad (7)$$

By combining (5) and (7) and integrating hin the limits of certain pressure changes the field and vapor, as compared to the essure in the case of a plane surface of the uid-gas boundary, we will arrive at the lowing formula:

$$v_l \Delta p_l = \frac{RT}{N} \int \frac{dp_v}{p_v} \text{ or } v_l \Delta p_l = \frac{RT}{N} \ln \frac{p}{p_0} \qquad (8)$$

ere Δp_l — change of the pressure in the uid as compared to the pressure in the case a plane boundary surface and unlimited uid layer thickness; P_0 — vapor pressure the case mentioned; and p — vapor pressure ler the changed conditions.

Formula (8) provides that:

$$\frac{p}{p_0} = e.^{Nv_l \Delta p_l / RT.} \qquad (9)$$

The volume occupied by the liquid gam- lecule Nv_l can be expressed by the gam- lecule mass, M, and liquid density, ρ, as lows:

$$Np_l = \frac{M.}{\rho} \qquad (10)$$

Thus, (9) can be changed as follows:

$$\frac{p}{P_0} = e.^{M \Delta p_l / RT\rho} \qquad (11)$$

From this we can see that the vapor pressure ve liquid surface is determined by the pres- e decrease, Δp_l, in moving across the liquid- boundary, provided that the concentration lissolved substances remains unchanged. en this pressure decrease is determined the boundary surface curvature and is ex- ssed by the Laplace formula,

$$\Delta p_l = \sigma \left(\frac{1}{r_1} + \frac{1}{r_2}\right),$$

ation (11) assumes the folowing form:

$$\frac{p}{p_0} = e^{\sigma M \left(\frac{1}{r_1} + \frac{1}{r_2}\right) / RT\rho}.$$

For a convex meniscus, characterized by main curvative radii, $r_1 = r_2 = + r$, we will e the following expression:

$$\frac{p}{p_0} = e^{2\sigma M / RT\rho r},$$

for a concave meniscus with $r_1 = r_2 = -r$, ill be:

$$\frac{p}{p_0} = e^{-2\sigma M / RT\rho r}.$$

As has been demonstrated by a number of erimental studies (1, 2, 3), a thin liquid er on a solid base can be in the state of ilibrium with the main liquid volume, vided that its surface is under certain itional pressure equal to the pressure de- oped within the thin liquid layer itself. The er pressure is called disjoining pressure.

t has been also shown (6, 7, 8) that such an ilibrium can also be maintained without additional pressure, but provided that the ssure of the main liquid volume, adjoining thin liquid layer, is reduced (for instance, ause of the meniscus curvature along the boundary of soil moisture). These conditions make possible an equilibrium between the film liquid pressure and the volume liquid pressure.

It follows that the pressure decrease in moving across the liquid-gas inter-phase surface of thin liquid layers on a solid base occurs in exactly the same manner as in moving across a curvilinear boundary surface of a volume liquid. When the disjoining pressure is positive, it is counterbalanced by a reduced pressure within the layer, and when the disjoining pressure is negative (as, for instance, is the case with free pure liquid films adjoined on both sides by gases), it is counterbalanced by an increased pressure within the layer. Therefore, for our purpose we can draw the following equation:

$$\Delta p_l = - p_p,$$

with P_p symbolizing the disjoining pressure. It means, in effect, that the pressure in the liquid films around soil material particles is lower than the atmospheric pressure, and that the difference is expressed by the disjoining pressure. The formula for vapor pressure above such films can be then expressed as follows:

$$\frac{p}{p_0} = e^{-MP_p / RT\rho.} \qquad (12)$$

If we are to compare vapor pressure above liquids with a varying concentration of the dissolved substances — C, we can express the ratio $p:p_0$ by following the concept that the chemical potential of a dissolvant decreases as compared to a dissolvant with a lesser concentration of dissolved compounds, by the factor (4):

$$\Delta \mu = - (c_2 - c_1) RT,$$

assuming that c is the ratio between the number of molecules of dissolvant and dissolved substances $c = \frac{n}{N}$, and that the symbols 1 and 2 refer to two dissolvants with different concentration ($c_2 > c_1$). Then, by anology with expression (8), we can say that:

$$- (c_2 - c_1)\ kT = \frac{RT}{N} \ln \frac{p_2}{p_1}.$$

If $c_1 = 0$, then the equation will be:

$$\ln \frac{p}{p_0}\ ckTN/RT. \qquad (13)$$

Here p_0 represents vapor pressure above a pure liquid and p – above a solution.

If we take into account that the osmotic pressure is $\Delta p_{osm.} = \frac{ckT}{v_l}$ then (13) can be changed to read as follows:

$$\frac{p}{p_0} = e^{-Nv_l \Delta p_{osm} / RT}$$

or, considering (10), that it is:

$$\frac{p}{p_0} = e^{-M \Delta p_{osm} / RT\rho} \qquad (13')$$

It follows that when the osmotic pressure is positive, Δp_{osm}, the vapor pressure above a solution decreases. At the same time, when there is a positive pressure increase caused by changes in the surface curvature or by a negative disjoining pressure in the thin layer (which, as we have pointed out, increases the pressure in the layer liquid), the vapor pressure above the surface of a liquid increases.

Let us finally consider the case of an equilibrium distribution of liquid in the form of films and wedge moisture in a soil profile, and then formulate the equilibrium for the vapor distribution in its pores.

As has been stated in earlier works (6, 7), when there is an equilibrium, the pressure in films and wedges moisture is distributed in accordance to the hydrostatic law. The pressure in all moisture elements is lower than atmospheric and the difference is expressed by this equation:

$$\Delta p = -\rho gh, \qquad (14)$$

where h stands for the height of the point under study above the ground-water horizon. This condition (14) is assured either by the curvature of wedge moisture menisci,[1] or by the adjoining pressure inside of thin moisture films. In both cases the liquid pressure decreases.

By supplementing formula (11) with Δp from (14), we can express the water vapor pressure in relation to the moisture in a soil profile:

$$p = p_0 e^{-Mgh/RT},$$

representing an established barometrical formula defining the equilibrium vapor distribution above a liquid surface.

It follows that, if the conditions for an equilibrium should be disturbed for the condensed liquid phase, they will be disturbed for the vapor phase. For instance, if in a certain element of wedge moisture the pressure should decrease, as compared to the surrounding elements, meaning a decrease in the curvature of concave menisci (this would be accompanied by an increase of the soil moisture), then the vapor pressure in this place would increase and the vapor would commence to move toward menisci with smaller radii of curvature. In other words, vapor would move in the same direction that would condensed liquid. The same effect would be evident if the thickness of moisture films should increase. As can be seen from formula (12), the vapor pressure is greater above thicker moisture films and, therefore, vapor movement would be in the direction of lesser film thickness.

The above considered conditions for an interphase equilibrium permit us to point out the following erroneous concepts of Shapovalova's theory:

1. Shapovalova assumed that, since in the case of a positive osmatic pressure the vapor pressure above solution surface decreases, it should follow that, by analogy, a pressure increase caused by the boundary surface curvature must also lead to the same result. As has been shown previously, this actually is not the case.

2. Shapovalova presumed that because of increased pressure in thin moisture films around solid particles the vapor pressure above them decreases. In reality, however, the pressure in such films is decreased, as compared with that of the adjoining gas medium.

3. These false concepts led Shapovalova to an erroneous conclusion that, in general, any increase of pressure in the liquid phase leads to a decrease of vapor pressure above this phase. On the basis of this, she finally concluded that the isothermic distillation through the gas phase must be ocurring in the direction from concave to convex menisci.

4. By assuming that the Thomson formula is incorrect even in its qualitative aspect, Shapovalova rejected the validity of the capillary pressure formula for liquid bound by curvilinear surfaces. Our equation (11) illustrates this point.

We did not intend to call upon well known experimental data, provided by various branches of science and techniques, in support of the validity of the Thomson formula. Instead, we limited ourselves to only such proofs which could reveal the basic misconceptions on the part of the author of this erroneous theory.

In conclusion, we should like to state that further development and popularization of Shapovalova's theory could only damage research efforts pertaining to the real regularities of moisture movement in soils.

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[1] Since the boundary inter-phase moisture mensici have a double curvature, a pressure decrease would not occur under all moisture conditions. When moisture content is high, the geometric outline of the mensici may be such that the liquid pressure would be not smaller, but greater than the atmospheric pressure. Hence, the vapor pressure above such mensici would be greater than above plane surfaces. This is precisely why soil is drying when the change from the moisture corresponding to the field moisture capacity to the moisture corresponding to the maximum molecular moisture capacity is occurring.

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WIND EROSION OF COARSE-TEXTURED SOILS PAVLODARSKAYA OBLAST'

L. F. SMIRNOVA, Moscow State University

Wind erosion of coarse-textured soils (deflation) is a very common phenomenon. It affects especially seriously virgin-land districts in which large continuous areas have been plowed without paying enough attention to antideflation measures. Thus, in three years (1955-1957) 400,000 ha of crops in Pavlodarskaya Oblast' were either destroyed or damaged by erosion (1, 2, 3).

In 1956, the Department of Soil Physics and Melioration, Moscow State University, conducted a study of wind erosion on coarse-textured soil in Beskaragaysk District, Pavlo-

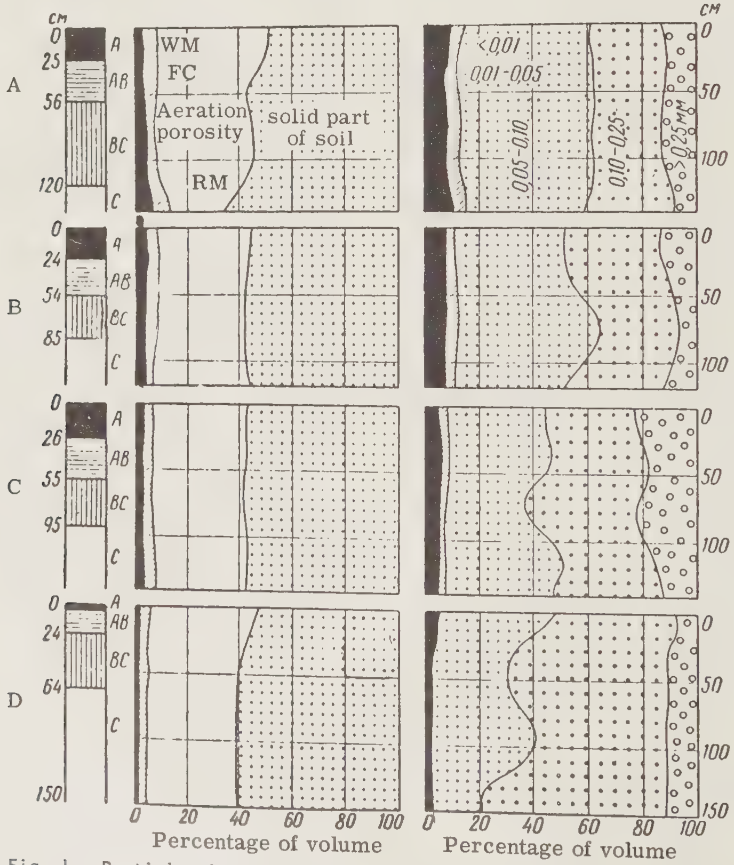

Fig. 1 - Particle-size analysis and hydrophysical properties of chestnut cohesive sand and pine forest loose sandy soils.

A - Profile 9, slightly eroded soil; B - Profile 3, moderately eroded soil; C - Profile 7, strongly eroded soil; D - Profile 1, pine forest soil under forest.

Table 1

Particle-size analysis and hydro-physical properties of sandy chestnut soils of "Put' k Kommunizmu" kolkhoz

Horizon	Depth, cm	Content of separates,* in % of completely dry weight						Particle density	Bulk density, g/cm³	Total porosity, %	Water permea-bility, mm/min.	Moisture properties, % of completely dry weight				
		>0,5	0,5–0,25	0,25–0,10	0,10–0,05	0,05–0,01	<0,01					MH[a]	WM	MFC	FMC	RAM
							Tract I. Slightly eroded soil. Profile 9.									
A	0—25	1,7	10,5	25,4	47,2	4,9	10,3	2,57	1,25	52,0	1,9	1,76	2,28	7,66	41,6	5,38
AB	25—56	1,4	9,6	26,2	50,3	4,8	7,7	2,65	1,48	44.2		1,70	2,21	6,12	29,8	3,91
BC	56—120	1,5	10,7	25,4	49,7	4,2	8,5	2,65	1,46	44,9		1,76	2,28	5,85	30,7	3,57
C	120	0,7	7,9	31,7	45,1	4,5	10,3	2,62	1,74	33,6		2,50	3,251	—	19,3	—
							Tract II. Medium eroded soil. Profile 3.									
A	0—25	1,3	13,6	34,6	41.7	2,6	6,3	2,67	1,51	43,4	5,1	1,41	1,83	4,65	28,7	2,82
AB	25—55	1,0	11,8	35,7	41,7	3,2	6,2	2,65	1,56	41,1		1,68	2,18	5,54	26,4	3,36
B	55—105	0,4	6,9	30,9	51,9	4,0	6,9	2,62	1,53	41,6		1,65	2,14	5,44	27,2	3,30
C	105—120	1,2	14,4	37,5	37,6	2,4	7,5	2,65	1,55	41,7		1,34	1,74	4,22	26,9	2,49
							Tract III. Heavily eroded soil. Profile 7.									
A	0—27	2,3	20,1	33,1	36,8	1,8	5,8	2,63	1,52	42,2	4,9	1,12	1,45	3,96	27,7	2,51
AB	27—54	2,2	15,0	36,2	38,2	2,4	5,9	2,64	1,55	41,3		1,36	1,77	4,39	26,6	2,62
B	54—95	2,0	20,0	40,7	31,1	1,1	5,2	2,65	1,54	41,8		1,16	1,51	4,09	27,2	2,58
BC	95—125	2,1	13,3	31,2	46,4	1,5	5,5	2,65	1,53	42,2		1,18	1,53	3,57	27,6	2,04
C	125	2,7	10,9	39,4	40,8	1,1	5,2	2,63	1,52	42,2		1,56	2,03	5,22	27,7	3,19

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[a] MH - maximum hygroscopicity; WM - wilting moisture; MFC - minimum field capacity; FMC - full moisture capacity; RAM - range of available moisture.

Note: Comma represents decimal point.

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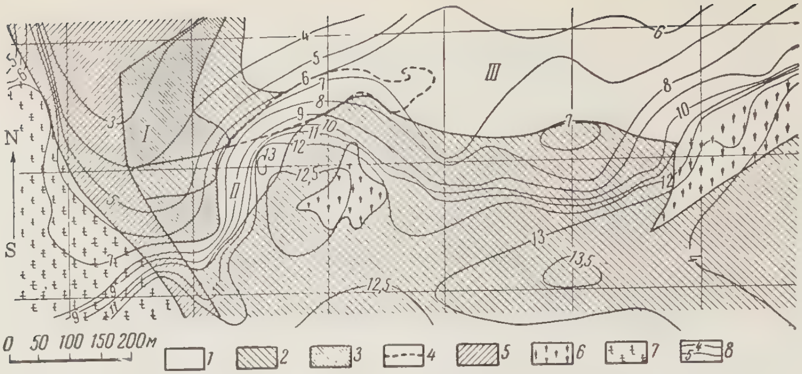

Fig. 2 - Map and geomorphological profile of the experimental field.

1 - Strongly eroded soil; 2 - moderately eroded soil; 3 - slightly eroded soil; 4 - boundary line of wind-protected area; 5 - pasture; 6 - wild rye; 7 - pine forests; 8 - contour lines with conventional designations.

was transported in the air layer below 15 cm (Table 2).

The results of a particle-size analysis of the material carried by the wind at various heights and intercepted by Znamenskiy samplers (Table 3) showed that sand particles >0.5 mm in diameter move only on the soil surface; the <0.5 mm particle diameters rise to a height of 15 cm; and only the particles <0.1 mm in diameter rise to a height of 30 cm or more.

As a result of the loss of the fine particles, sorted sand is left on the surface (82 %of the particles are 0.5-0.10 mm in diameter), containing only 4% of physical clay, as compared to 7%-8% in non-eroded soil. Aeolian deposits form a ripple pattern with large sand grains accumulating at the crests.

The experimental field in the "Put' k Kommunizmu" kolkhoz might be divided into three sections according to the degree of soil erosion (Fig. 2):

Tract I (Profile 9), situated in the lower part of the field protected from W and SW winds by a pine stand. This area has almost fully retained its humus horizon. The degree of its enrichment in sand (loss of fine earth by wind) was small.

Tract II (Profile 3, NW wind — exposed slope) lost a part of its humic horizon and the rest was considerably enriched in sand in the upper 20 cm layer. A dust storm on May 13 blew away all the corn seeds sown on May 12.

Tract III (Profile 7, northern lower part of the field — the zone of aeolian sand accumulation in wind-protected areas) lost much of the fine earth from the entire thickness of its humic horizon. The soil is covered with aeolian and deposits. On May 13, the corn seeds were buried here during the dust storm to a depth of 12-15 cm.

As a result of another dust storm on May 29, all corn seedlings on Tracts II and III were damaged (cut by flying sand). On Tract I they were not damaged. The drought ended in June and was followed by rainy weather with 36 mm of precipitation during one month. The soil, which still retained some of the spring moisture, was now wet to a depth of 100-120 cm, and it took only a short time for the damaged corn plants to recover. The total mass of the corn (including weeds) per square meter was at this time 30 g (air-dry weight) for Tract III and 175 g for Tract I, and by the end of July it had increased to 110 g and 420 g, respectively. Thus, non-eroded soil produced four to five times more than strongly eroded soil.

Finally let us consider how erosion affects the properties of sandy chestnut soil. Table 1 shows that, as a result of intensified erosion, the content of physical clay in A horizon was 10%, 8% and 6%, respectively, for slightly, moderately, and strongly eroded soils. The loss of physical clay caused an increase in soil permeability from 2 (Tract I) to 5 mm/min (Tract III). The water-holding capacity (MFC) decreased in A horizon from 7%-8% to 4%. The maximum hygroscopicity decreased by 0.3%-0.4%. The amount of water not available to plants (WM) also decreased but, at the same time, there was a decrease by 1.5%-2.0% in the range of available moisture (RAM).

Thus, as a result of the loss of fine earth, the hydrophysical properties of the soil became less favorable for plants. Along with the fine earth, the soil lost much of its nutrients (Table 4). As compared to the slightly eroded soil (Tract I), the strongly eroded soil (Tract III) contained in the physical clay of its upper layer, 1.5 times less phosphorus, 2.5 times less humus, and 2 times less nitrogen and potassium than soil erosion (Tract I).

Analysis of soil samples from cultivated land in Beskaragayskiy District showed (Table 4) tha in three years of plowing the sandy chestnut soil lost the following percentages from the plow layer (the loss is calculated by taking the virgin lands as 100%): fine earth — 37% (61 metric tons/ha); humus — 67% (23 metric tons/ha); nitrogen — 37% (840 kg/ha); potassium — 35%

03 kg/ha); and phosphorus — 15% (56 kg/ha).

During the same period meadow-chestnut ndy loams in the area served by the Semi-rsk Machine Tractor Station lost the follow-g amounts and percentages of the same aterials: fine earth — 60 metric tons/ha 1.5%); humus — 42 metric tons/ha (63%); trogen — 2.5 metric tons/ha (67%); potassium 333 kg/ha (55%); and phosphorus — 280 kg/ (50%), approximately the same data were obined by Yakubov (4).

On the basis of the information discussed, can conclude that the plowing of large areas sandy soil in regions affected by droughts d wind erosion is permissable only when a stem of crop rotation with a heavy emphasis perennial grasses is in effect. Protective rest shelterbelts could also play a major role.

Received May 4, 1959

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SOIL EROSION AND ITS EFFECTS ON YIELD IN AREAS OF THE VOLGA UPLAND

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Water and wind erosion are very harmful to the national economy. In many areas of the Soviet Union, agriculture is suffering from it. One such area is the region on the right bank of the Volga (from Gor'kiy to Stalingrad), which occupies most of the Volga Upland. In intensity of active water erosion and gully formation this area is second only to the Central Russian Upland in the whole of the European USSR.

Soil erosion on the Volga Upland, as well as in other areas of the USSR, is a serious liability inherited by us from the pre-revolutionary past with its predatory attitude toward land as a means of production. For many centuries, as farming developed in the region on the right bank of the Volga, forests were destroyed by cutting and fire, and watersheds and steep slopes were indiscriminately plowed. The excessive expansion of the plowed area, as commercial grain developed in this part of the country, was the cause of the soil erosion and gullies that appeared in the post-reform period. Forest-steppe and steppe parts of the region were affected (10%-12% erosion, on the average, and up to 20% erosion in some areas next to the Volga River). This catastrophic rate of erosion had its pernicious effects on crop yields, runoff, natural grass composition of pasture land, etc. Thus, the Volga Upland developed an erosion landscape just as unattractive as that found in the central chernozem regions.

The Socialist economic system has created opportunities for the progress and rational management of farming and, thus, for overcoming soil erosion, but these opportunities are not being used to full advantage, and since the destructive effects of erosion are not fully appreciated, soil erosion and gully formation continue. It has been determined, through investigations under the auspices of the Academy of Sciences of the USSR, that in the Volga Upland the heads of gullies are extending 3-4 m a year, on the average. During years with frequent heavy showers the rate of annual growth is 8-10 m. We witnessed a case of this on the bank of the Volga in Krasnoarmeysk and Zolotovsk Districts, Saratov Region, after the heavy spring-summer showers in 1958.

Scores and even hundreds of hectares of arable land have been abandoned during the last 30 years by many kolkhozes and sovkhozes because of sheet erosion, scour, gully formation, deflation, alluvial deposition on plowland and hayfields, water-logging of bottom lands, etc. In some kolkhozes situated on the Volga slope of the Upland, the destruction of agriculturally useful lands is very intense. For instance, one kolkhoz in Zolotovsk District has lost 14.3% of its arable area during the last 25 years. In the same kolkhoz, almost one-third of the pasture land on the slopes of the chalk hills facing the Volga is practically unusable. On another kolkhoz in the same district large areas have become useless "trash" lands (Fig. 1).

Soil erosion presents just as great a danger to the western slope of the Upland. For instance, during recent years one of the kolkhozes in Terengul'sk District (Ul'yanov Region) has lost 200 ha of plowland and 175 ha of pasture land because of the growth of gullies, sheet erosion, and silting of the Usa River flood plain. On kolkhoz in Krasnoarmeysk District, 230 ha of plowland have not been used for several years because of lengthening and widening of gullies. These examples give a fairly good idea of the extent of the danger from erosion and of the fact that the Volga Upland is at present acutely affected.

Sheet erosion is reducing the yields of almost all crops, especially row crops. This fact has been noted by many investigators. But until now most of the investigations in this field were conducted in the Central Russian Upland, where convex slopes predominate. This is not the case with the Volga Upland. Here we find more complex and diversified slope profiles. Convex slopes alternate with concave or long terraced bluff slopes combined with short, low bluffs. In addition, on narrow watersheds of the mesa type, there are stony-sandy hills (in the forest-steppe areas) or rocky plateaus (in the steppe areas). The erosion pattern here is complex and mosaic-like. On the highest elevations with exposed sandstone and marl, the soils are immature, deflated, and full of fragments; these give way to strongly eroded soils on steep slopes and alluvial soils on terraces.[1] The crop yields of the fields shows a corresponding complex mosaic pattern.

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[1] For more details see Armand's article (5).

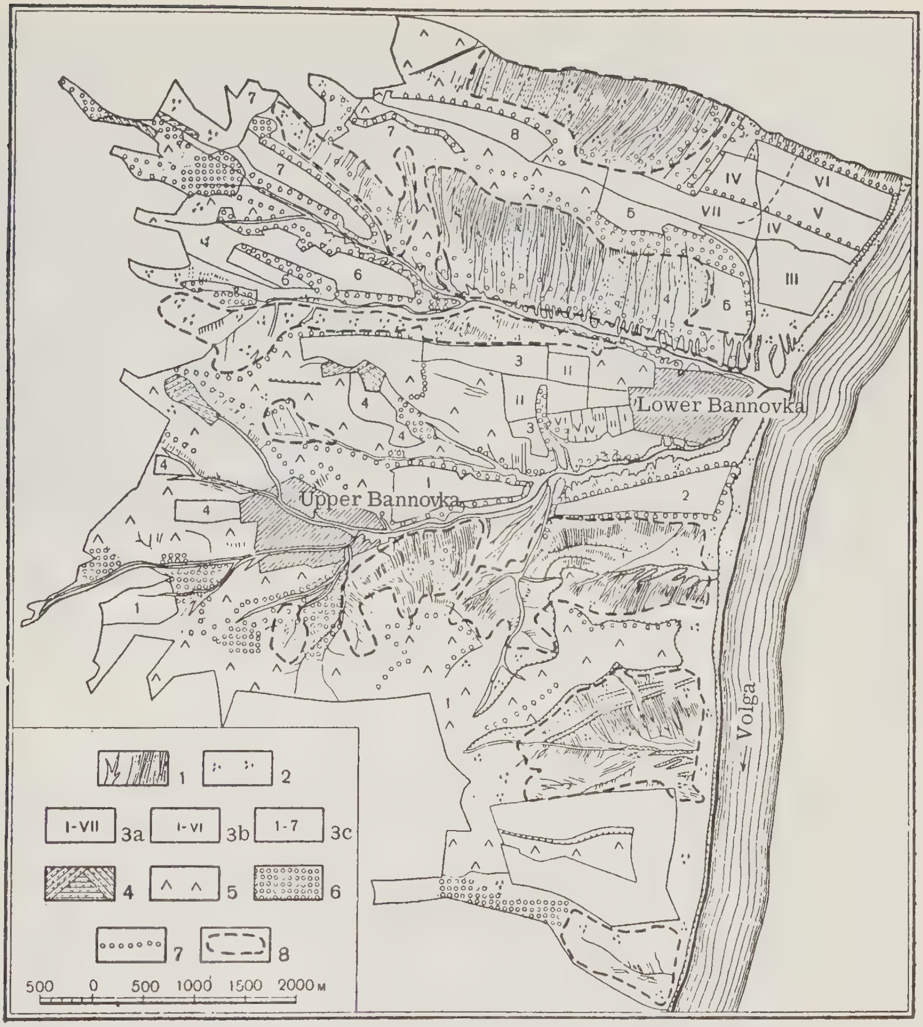

Fig. 1. - Dissection by the revine-gully-valley network and land use in Zolotovsk key tract, Saratov Region.

1 - ravines, gullies, rills; 2 - stoney areas; 3 - crop rotation fields; a - field crops; b - subsistence; c - meadow-pastures; 4 - vegetable gardens; 5 - pastures; 6 - orchards and berry patches; 7 - forest shelterbelts and plantations; 8 - formerly farming lands reduced by erosion to poor "trash" lands.

Antropov (1) has established a relation be- een rye yields and the degree of soil erosion the Volga Upland. But he has been unable to the same thing for other crops, because the vere drought of 1953 had a very bad effect on ch spring crops as wheat, barley, and others.[2] In 1958, we had the opportunity to carry out investigations of this sort under exceptionally favorable weather conditions.

We decided to determine quantitatively the correlation between winter and spring crop yields, on the one hand, and the degree of soil erosion, the relief pattern, the number of gullies per unit area, slope exposure, and other features of the erosion landscape, on the other hand. We wanted then to relate our biometric and yield data to the whole complex of natural properties on certain specific tracts singled out by Armand (5) in the Krasnoarmeysk Key area.

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[2] Because of a severe spring-summer drought, nter rye was also very retarded in 1953. Hence e decreased yield of this crop was caused not so uch by soil erosion and "erosional" drought, as by mospheric drought.

The Krasnoarmeysk key area is situated in the steppe zone on the western slope of an elevation in the basin of the Karamysh River, a tributary of the Medveditsa. The area is divided by three large ravines, whose slopes are covered by a network of second-order ravines and gullies 6-7 m deep, up to 9 m wide, and as long as 2.5 km. The floors of the ravines and the gully network occupy 2.75% of the total cultivated area. Erosive processes are pronounced but wuite irregular. The southeast and northwest terraced slopes along Talovka ravine and the western slope descending to the Karamysh flood plain are the very strongly eroded. The southern chernozem developed on diluvial clay loams and the parent materials (sands, marls) is the main soil group. It covers three-fourths of the whole area. Dark chestnut soils have developed in several places, mostly on the steepest slopes of southern exposure, and alluvial-sod and meadow soils on the Karamysh flood plain. According to the data furnished by Bespalova (6), strongly and very strongly eroded soils occupy 9.3% of the total area; moderately eroded soils, 25.5%; and water-deposited soils 10.6%.

In our investigation we studied profiles along the slopes in different areas of three tracts (Fig. 2) sowed to the following crops: spring wheat, barley and winter rye (Fig. 3). The three tracts were as follows:

a) Tract VI. A slightly convex east-west plateau of the Talovsk-Panitsk watershed, ranging from 1 to 1.5 km in width, with most slopes less than 1°. The over-all horizontal dissection amounted to 1.0 km/km². The predominant soil here is a southern, moderately thick, moderately rubbly chernozem on

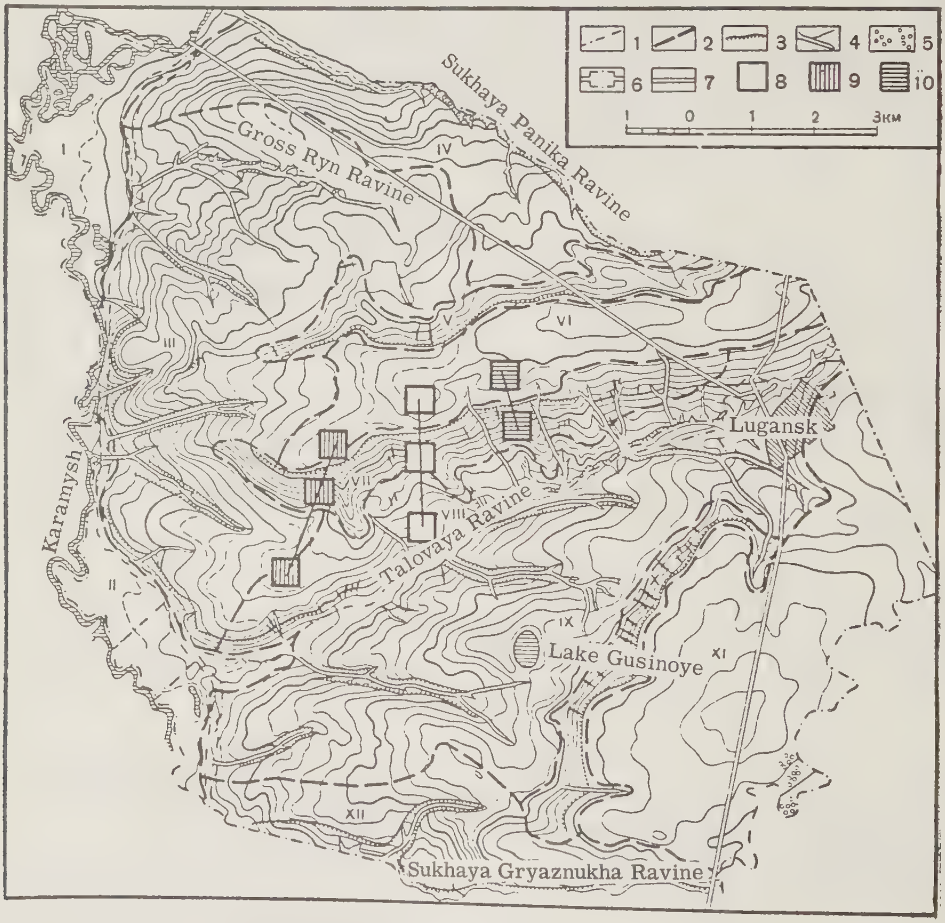

Fig. 2. - Sketch of tracts and location of experimental crop plots in the Krasnoarmeysk key tract.

1 - dividing lines between Kolkhozes and brigades; 2 - tract boundaries; 3 - ravine bluffs and terrace benches; 4 - gullies and rills; 5 - shrubs; 6 - railroad right-of-way; 7 - unpaved roads; 8 - spring wheat exp't. plots; 9 - barley exp't. plots; 10 - winter rye exp't. plots.

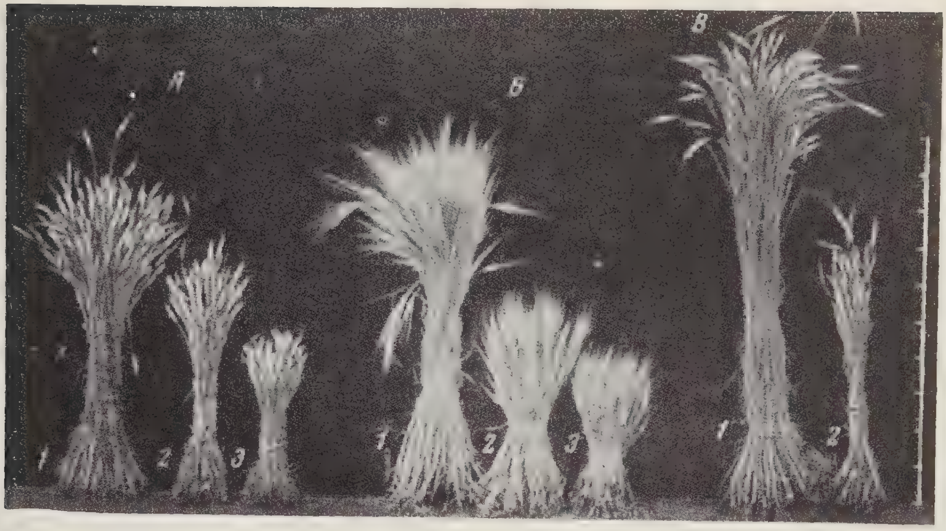

Fig. 3. - Crops from 1 m in experimental plots.

A - spring wheat, and B - barley on the plots; 1 - VII - on alluvial soils; 2 - VI - on slightly eroded soils subject to deflation; 3 - VII - on strongly eroded soils; C - winter rye on plots; 1 - VI - on slightly eroded soils subject to deflation; 2 - VII - on strongly eroded soils.

ent materials. Deflation occurs on the teau and suffosion-caving processes in de- ssions. Sheet erosion of the soil is slight.

b) Tract VII. A right-bank terrace of Talov- ravine. It faces SE, S and SW. The steep- s is 3°-8° or more; its height is about 40 m. tract is dissected by gullies and numerous ines, which are especially frequent in the tern part. The total horizontal density of section is 3.4 km/km² — considerably her than for Tract VI. The soils here are thern, shallow, eroded, moderately or quite bly chernozems on solid parent materials. dern geomorphological processes are re- d to strong sheet erosion and active linear sion.

c) Tract VIII. The gentle southern slope a narrow slightly sloped (up to 2°) lower race of Talovka ravine. The density of section here is considerably less than on terrace (Tract VII). The chernozems here southern, moderately thick and thick, and many places alluvial, in many places some gments. Modern geomorphological processes sist in soil deposition on terraces and a ht erosion on slopes.

For our studies, the crops on 10 m² plots on h of the three tracts were cut, dried, and eshed. Then the grain and straw were ghed separately. In addition, samples were en from the same plots to determine the ctural harvest on 1 m². The biometric re- s and yields are given in Table 1.

The results of our investigations make it sible to say whether land eroded to a partic- degree is better or worse than other land in the basic farming unit, the kolkhoz. Tract VIII, as can be seen from Table 1, has the highest crop productivity. This area consists of relatively level fields with alluvial moderately thick and thick chernozems and is very favorable for growing agricultural crops. Tract VI is, in comparison, much less favorable for farming because of its natural features of soil erosion and deflation. As a result, the crop productivity of Tract VI is twice lower than that of Tract VIII. Tract VII, which is situated on strongly eroded bench on the right terrace of Talovka ravine, has still a lower productivity. The yield here is approximately twice lower than on Tract VI and 3 to 4 times lower than on Tract VIII.

The area factor in the yield-tract relationship is very helpful not only in considering the effects of geographic differences on the productivity of eroded fields (this is very important for qualitative and economic land evaluation), but also in determining the relative profitability of various crops for different eroded fields.

In principle, a complete estimate to the relative land productivity and crop profitability must be based on the correlation between yield, on the one hand, and not only the natural land properties but also the methods of land utilization, on the other hand. But, since in this particular case the methods of land utilization are almost the same (crop rotation is not used, fertilizers are not applied, plowing is always done along the slopes), they do not have to be considered.

The data in Table 1 specifically indicate that it is hardly economical to grow winter crops on

Table 1

Crop yields on different tracts with varying degrees of erosion, "Lenin" kolkhoz; Krasnoarmeysk District. Saratov Region

Tract	Crop	Distance from plot to water divide, m	Slope exposition	Plot slope	Biometric and yield data							
					No. of stalks with ears per 1 m²	Mean height of plant	Mean length of ear	Mean number of grains per ear	Grain wt. from 10m²	Straw weight fr. 10 m²	Yield, cntr/ha	
						in cm			in kg		Grain	Straw
VI	Spring wheat	175	South	—0°20′	330	60	5	20	1,30	2,27	13,0	22,7
	Barley	0,0	SW	—0°40′	304	48	2,5	19	1,46	3,15	14,6	31,5
	Winter rye	525	SE	—0°20′	374	128	9	59	2,56	5,85	25,6	58,5
VII	Spring wheat	1010	South	—7°10′	260	43	2,8	11	0,85	1,53	8,5	15,3
	Barley	625	SW	—6°20′	224	33	1,5	13	0,72	2,05	7,2	20,5
	Winter rye	1400	SE	—8°	290	70	4,0	28	0,67	1,17	6,7	11,7
VIII	Spring wheat	2020	South	—0°20′	470	82	5,6	24	2,56	4,05	25,6	40,5
	Barley	2125	SW	—0°10′	402	90	4,5	37	3,73	5,76	37,3	57,6

Note: Comma represents decimal point.

the fields of Tract VII, because in winter these fields become completely windswept of snow, which drifts into the numerous gullies and expose the crops to wind and freezing. It would be more sensible here to grow crops which do not need to be plowed every year (perennial grasses, fruits, and berries) and forests.

The association of yields with complex of properties of the eroded landscape can be established not only at the Kolkhoz level but also for the administrative district and at higher levels. In the following paragraphs we consider this association for two administrative districts of the steppe zone: Krasnoarmeysk District and Zolotovsk District. By using Lidov and Setunskaya's (12) erosion map for the Volga upland and some additional indexes of dissection and gully area, we can distinguish the following erosion districts.

Krasnoarmeysk District

I. Slightly eroded. In the northwest part of the district, on the western slope of the Upland, where gullies occupy 1.3%-2.5% of the land area of four agricultural enterprises. Watersheds[3] here are relatively wide (up to 4 km) and the average surface slope is insignificant (less than 20 m per 1 km of slope length). Strongly dissected relief constitute about two-thirds of the total denuded area. The density[4] of the ravine network is more than 1.5 km; and that of the gully network, from 1 to 2 km. The plowland area is very high (78%-85%). The plain area of the watersheds is covered with a thin chernozem that is low in humus (on compact parent materials — marls). The larger area of the hilly plain is covered by southern chernozem moderate thickness and low in humus (clays and fine clay-loam silty soils developed on deposits). Present erosive processes are weak.

II. Moderately eroded. In the central part of the district (Karamysh River basin), where gullies occupy 2.3%-3.4% of the land area of six kolkhozes and sovkhozes. The width of the watershed and average slope are here the same as in the erosion district previously. Highly dissected relief constitutes half of the denuded area. The ravine network has a density of 1.1.5 km; and the gully network, 0.5-1.0 km. The plowland area is high: 60%-78%. The predominant soils are southern moderately thick and thin chernozems that are low in humus (on sandstones and sands). Large areas are covered with immature chernozems (soils of steep slopes on sandstones and sands) and solonetzic chernozems that are low in humus along the upper and middle reaches of the Karamysh River. Present erosion activity is moderate.

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[3] Here, and below, we mean the width of the watershed between the heads of two ancient erosion forms on opposing slopes.

[4] Density of ravine network — half the distance between the thalwegs of two adjacent ravines; density of gully network — mean distance between slope gullies.

III. Strongly eroded. In the southern part
the district, which includes the watershed
ateau between the Karamysh and Ilovlya
vers. Gullies occupy 2.6%-4.2% of the land
ea of three sovkhozes. Watersheds here
e considerably narrower (less than 2 km)
d the slopes are greater (20-50 m) than
osion Districts I and II, while the density
ravine and gully networks is the same. The
owland area (thin chernozems low in humus
sandstones and marls) is 25%-60%. On the
per reaches of the Ilovlya River and its tribu-
ries, large areas are covered with solonet-
c chernozems low in humus. Present (accel-
ated) erosion is evident almost everywhere.

IV. Very strongly eroded. In the north-
stern part of the district on the short, steep
lga slope of the Upland, showing maximum
ssection with ancient (normal) and present
ccelerated) erosion. About two-thirds, and
many cases all, of the area is cut by ravines
d gullies, which resemble deep gorges when
en from Volga. Gullies occupy 4.3%-13% of
e land area of three kolkhozes and sovkhozes.
addition, the Volga slope is covered with a
eat number of rills, waterways, gully-heads
d small growing gullies, which could not be
operly evaluated. Watersheds here are
rrow (less than 2 km); slopes reach 50 m;
e ravine-network density is less than 1 km;
d the gully-network density is less than 0.5
. Because of the extensive dissection, the
owland area barely reaches 25%. The soils
re consist of a thin chernozem low in humus
compact parent materials, (marls, lime-
ones) and immature chernozem (covering
eep slopes). These soils have been most
rongly eroded by wind and water; eluvium of
e parent materials, and often even the parent
terials themselves, are exposed.

Zolotovsk District

V. Slightly eroded. In the northern plain
ea of the district, where gullies occupy up to
% of the land area of eight kolkhozes. The
rphological erosion indexes are the same
for Erosion District I. Between one-half
d two-thirds of the land area is under cul-
ation. The soils here are southern cherno-
ms (clay and fine clay-loam soils on deposits),
n chernozems low in humus (on sandstones
d sands), and dark-chestnut soils. The sheet
d gully erosion of these soils is slight.

VI. Strongly eroded. In the southern "hilly"
t of the district, where gullies occupy 4.3%
% of the land area of six kolkhozes. The
rphological erosion indexes are same as
Erosion District IV. The plowland area is
%-50%. Immature chestnut soils predomin-
s on the steep, heavily dissected Volga
pes, and dark-chestnut soils; and thin
ernozem low in humus (on sandstones and
ds), on the western slope (beyond the Volga-
vlya water divide). These soils are subject
very severe erosion.

Crop-yield data (average figures for the
3-1957 period) in these districts are given
Table 2.

As Table 2 shows, yields of row crops (corn, sunflowers, potatoes, millet) are most affected by the erosion intensity and the degree of dissection. Comparison of these data with those presented in earlier studies (19) strongly suggests that, although in the plain regions the yields of grain crops and legumes have markedly increased, in these eroded districts yields have not increased by even a centner between 1953 and 1957 (as compared to the previous five-year period). Yields of spring wheat — grain crop most sensitive to soil erosion — actually even declined between 1953 and 1957, as compared to the 1948-1952 period. This was especially true in the extensively eroded sub-districts on the Volga slope of the Upland.

It must be admitted that at present, while there is a considerable crop-yield increase for the country as a whole, the eroded land still have lower crop yields than at the end of the 19th century.

It would be erroneous to think that crop yields depend exclusively upon the degree of erosion. Equally important are such other factors as, in particular, as the level of agricultural skill in different farming enterprises.[5] However, since our investigations were so broad in scope and encompassed such a long period (28 farming enterprises for five years), the results amount to a statistical proof of the fact that the common reason for the yield differences in this case were soil erosion and dissected relief.

The rapid growth of agricultural production envisaged by the "Control figures for the development of the national economy of the USSR from 1959 to 1965" and endosred by the 21st Congress of the Communist Party of Soviet Union calls for a yield increase of all crops. In this connection, the task of increasing crop yields in the Volga Upland as well as in other districts subject to dissection and erosion assumes proportions of national importance. It must be given urgent attention. The achievement of large yields on the basis of scientific farming methods appropriate for each erosion district and for each individual farming enterprise would also mean an important contribution to the over-all effort of erosion control. We have established how much crop yields depend on the degree of erosion and dissection. But the reverse is also true: the larger are crop yields and the better the development of the vegetation and its roots, the greater is the resistance of the soil to water erosion.

One of the reasons for low crop yields is the decreasing quantity of seeds sowed per unit area. This has been happening everywhere and always in the districts in question. Actually, it would be much more rational to sow full seed quotas on smaller areas only, than to waste seed on strongly and very strongly

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[5] Experience shows that the modern agricultural methods can reduce erosion damage and contribute to higher crop yields. This is true, however, only when these are specialized methods for erosion control.

Table 2

Average crop yields in eroded areas of the steppe zone in the region along the right bank of the Volga (Saratov Region) for the period 1953-1957, cntr/ha

Districts	All grain and leguminous crops	Including			Millet	Sunflowers	Potatoes	None
		Winter rye	Spring wheat	Barley				
Krasnoarmeysk District								
I. Slightly eroded	4,7	7,3	3,4	6,1	4,9	1,7	None	34,3
II. Moderately eroded	3,9	6,4	2,2	5,4	3,0	1,5	"	24,3
III. Strongly eroded	3,5	4,9	2,8	4,9	2,3	0,8	"	22,1
IV. Very strongly eroded	3,6	5,4	2,2	4,3	2,3	1,0	"	16,7
Decrease in yields in District IV, in percentage, as compared to District I	23,4	26,0	35,3	29,5	53,1	41,2		51,3
Zolotovsk District								
V. Slightly eroded	4,2	6,0	2,6	5,5	4,3	1,9	24,5	12,4
VI. Strongly eroded	3,6	5,1	2,4	5,0	3,0	1,3	19,9	8,8
Decrease in crop yield in District VI, in percentage, as compared to District V.	14,3	15	7,7	9,1	30,3	31,6	18,8	29,1

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[a] Data for 1956 and 1957.

Note: Comma represents decimal point.

eroded inter-ravine and inter-gully areas.

Mineral and organic fertilizers are an effective means for increasing crop yields. But on the Volga Upland they have not up to now been applied either in adequate quantities or to the areas which need them most.

Increased crop yields depend to a great extent on measures for the conservation and control of water. Therefore special attention should be given to forest shelterbelts, various kinds of water reservoirs and water ways, sowing or cover-crop strips, and after harvest leaving high stubble on the field, use of deep plowing and discontinuous harrowing (2, 4, 5, 7, 10, 11, 13, 15, 18, 21).

The following administrative-organizational measures for controlling erosion and increasing yields are especially important: 1) establishing a correct ratio for the main types of land utilization: plowland, meadow, and forests (as well as their correct distribution in accordance with the terrain features (3, 8, 17, 19); introducing and developing proper rotation with special emphasis on soil-protecting meadow-pasture of crop rotations and perennial grasses on areas not included in the crop rotation (3, 4, 5, 8, 9, 10, 14, 15, 17, 18, 21); 3) proper use of agricultural machinery, and above all the rational allocation of machines and fuel according to the degree of dissection of the land, and also the use of contour plowing only on slopes (4, 5, 15, 16, 17, 19, 20, 21); 4) rational crop specialization in erosion districts by taking into account their natural and economic conditions, as well as the problems of erosion control and the reclamation of eroded areas (19, 20).

There cannot be any doubt that the use of these measures will promtply result in checking erosion and thus increasing crop yields in accordance with the requirements of the seven-year plan for great agricultural progress.

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INVESTIGATION OF ORGANIC MATTER IN PODZOLIC COHESIVE SANDY SOILS

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This report presents the results of investigations of humic substances isolated by means of I. V. Tyurin's method from podzolic cohesive sandy soils (cultivated and forested).

1. The soils studied contained carbon in the following forms, expressed in percentages of total C:

a) in the top layers (0-30 cm): bituminous carbon, 3.6%-14.5%; carbon of Group I humic acids,[1] 11.7%-23.0%, or 80%-86.8% of total C in all humic acid fractions; carbon of Group II humic acids,[2] 2.3%-4.1%; carbon of Group I and II humic acids (C_h: I + II), 14.0%-27.0%; carbon of all fulvic acid fractions, 33.4%-42%; carbon of humin and ulmin fraction, 16.2%-43.9%.

b) in the subsurface layers (25-45 cm): bituminous carbon, 0.6%-13.0%. Thus, as compared to the top layers, the subsurface layers of the soils under study proved to contain less bitumen carbon.

Carbon of Group I humic acids, 12.8%-19.2%, or 73.0%-87.5% of total C in all humic acids. The top layers of the investigated soils contained more carbon in Group I humic acids (C_hl), expressed in percentage of total (C_0) soil carbon $(\frac{100 \times C_h{}^1}{C_0})$, as compared to the same layers of the cultivated soils.

Carbon of Group II humic acids, 2.2%-5.0%; carbon of Group I and II humic acids (C: I + II), 17.5%-22.4%; carbon of all fulvic acid fractions, 32.0%-43.8%; carbon of humin and ulman fraction, 25%-38%.

2. The ratio between the total C content in all humic acid fractions (C_h) and the total C content in all fulvic acid fractions (C_f), i. e., C_h:C_f, fluctuates between 0.40 and 0.57 for the cultivated soils and between 0.40 and 0.70 for the forest soils.

The C_h:C_f ratio shows that the soils in question definitely belong to the slightly-podzolized sod-podzolic soils.

3. The Group I humic acid fraction contains little P_2O_5: 1.67-8.0 mg of P_2O_5/100 g of humic-acid C. The Group II humic acid fraction does not contain P_2O_5. Extracts containing fulvic acids had somewhat more P_2O_5 than did extracts containing humic acids.

4. The Group I humic acids contained 6.5%-12.3% of the total N in the soils under study. The C:N ratio fluctuates in these acids between 16.7 and 21.5. In extracts from the upper layers containing acids, the C:N ratio varies from 5 to 10.5. The Group I fulvic acids (in the upper soil layers) have a higher nitrogen content, expressed as percent of total N $(\frac{N_f\text{I} \times 100}{N_0})$, than Group I humic acids $(\frac{N_h\text{I} \times 100}{N_0})$.

5. The optical density of the Group I fulvic acids proved to be less than that of the Group I humic acids of the same soils. It follows that the Group I fulvic acids of the soils under study must have a simpler molecular structure than the Group I humic acids.

6. The exchange capacity of the humus proved to be higher in the forest soils than in the cultivated soils.

7. These results indicate that the signs of podzolization, which appears in sandy forest soils when they are cultivated, remain in them for a very long time.

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[1] Humic acids free or weakly bound to the mineral and organic parts of the soil. They are soluble when the soil is treated directly with 0.1 N NaOH.

[2] Humic acids relatively firmly bound to the mineral and organic parts of the soil. They are soluble in alkali after decalcification.

) INTENSIFY THE DEVELOPMENT OF RATIONAL METHODS
)R FIELD AND LABORATORY SOIL INVESTIGATIONS

torial Board of Pochvovedeniye

During the recent years successes unprece-
ted in human history have been achieved by
science and technology of our country. The
gressive nature of the Soviet science has
n widely recognized throughout the entire
rld owing to such achievements as the con-
st of cosmic space, very long-distance
plane flights, great progress in the peace-
use of atomic energy, and the industrial
of semiconductors.

The 21st Congress of the Communist Party
he Soviet Union and the plenary sessions
he Central Committee that followed charged
industry and agriculture with the task of
ieving considerable increase in the pro-
tivity of labor through vast mechanization
automation of production.

This task concerns, among others, Soviet
l scientists and agricultural chemists.
en considered against the background of the
entific and technical achievements men-
ned previously, our current field and labora-
y methods of soil investigation appear to be
newhat obsolete.

It is true that during decades there have
n certain advances in this field. We can
ntion the application of aerial photography
arge-scale soil mapping, which saves time
provides a higher degree of accuracy; a
vibration drill (suggested by V. G. Petrov);
ter analyses, as a result of the spectral
thod, trilometry, and the use of such new
ipment as the electrophotocolorimeter,
erferometers, etc. A deeper study of soil
nponents and processes has been made
possible by the use of isotopes, the electron microscope, chromatography, and other modern methods.

However, on the one hand, these modern methods have not as yet been adopted by all of our leading soil and agricultural chemical research centers, to say nothing of provincial institutes and experiment stations. And, on the other hand, many soil investigation methods are still very time-consuming and sometimes not suitable for specific soil-research objectives and field and laboratory conditions. A good example of this is moisture determination by gravimetric and similar methods.

There have been considerable achievements in the USSR in standard studies of soil processes. But the methods continue to be time-consuming and imperfect. Modernization and automation of many analytical operations are long overdue. Soil science and agricultural-chemistry do not take full advantage of the experience of chemical research laboratories at home and abroad.

The editorial board of Pochvovedeniye presents in this issue a number of articles devoted to the problem of improving methods of soil analysis. At the same time, the editorial board appeals to all soil scientists, agriculture chemists, and other specialists to intensify their efforts in expediting and improving field and laboratory research methods. It also urges them to submit data on the results obtained for publication on the pages of our journal.

THE USE OF SODIUM PYROPHOSPHATE FOR ISOLATING FREE HUMIC SUBSTANCES AND THIER ORGANIC-MINERAL COMPOUNDS FROM THE SOIL

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It is an established fact that humic substances exist in soil in the following three forms: humic acids, humic acid salts with strongly basic cations, and complex alumo- and iron-humic salts. All these forms can exist either free or aggregated (attached) to the colloidal and coarser separates (1).

All variations of I. V. Tyurin's method for the fractional analysis of humus (2, 3, 4, 5) cannot be used to determine how the three humic substances and the mineral part of the soil are bound together. They can only show how stable these aggregates are. A direct treatment of soil with 0.1 N NaOH leads to the isolation of free and minimally aggregated humic substances. A further treatment with 0.1 N and 0.5 N H_2SO_4 and 0.1 N NaOH results in the isolation of more dehydrated and stable forms. This method cannot be used to isolate alumo- and iron-humic compounds because even weak mineral acid solutions destroy these compounds and extract part of the aluminum and iron from hydrated sesquioxides and other minerals. The aspect of this problem concerned with mineral forms of iron has been discussed in detail in Tsyurupa's work (16). Weak NaOH solutions also partially destroy alumo- and iron-humic compounds, converting aluminum and iron into hydrates. Aluminum partially (depending on NaOH concentration) goes into solution as aluminate, while the iron remains insoluble. In addition, 0.1 N NaOH partially dissolves mineral forms of aluminum existing as hydrated aluminum oxides and other forms.

Free humic substances and their alumo- and iron-humic derivatives not firmly aggregated with the mineral part of the soil can be isolated by means of sodium pyrophosphate. This solvent was first suggested by Bremner (7) who conducted extensive experimental investigations of humic substances. It is widely used in comparative studies of humic substances in various soils by German and Japanese researchesr (8, 9, 10). However, until now no attempt has been made to use this method to isolate alumo- and iron-humic compounds.

We conducted detailed investigations of the effects of sodium pyrophosphate on the soil in order to work out methods for the isolation of humic substances and their organic-mineral derivatives. Our objective was to study the mechanics of pyrophosphate action on the soil and to compare them with the effects produced by 0.1 N H_2SO_4 and $NaOH_7$ which are usually used in fractionation.

We examined a number of soils, parent materials, and artificial preparations. For the artificial preparations we used calcium humates, alumo- and iron-humic compounds derived from chernozem humic acid, as well as sesquioxide gels dehydrated to various degrees derived from aluminum and iron sulfates by ammonium hydrate precipitation and purified by usual methods.

Table 1 shows the effects of 0.1 N H_2SO_4 and NaOH and 0.1 M sodium pyrophosphate on the artificial preparations. Table 2 shows the effects of the same solvents on parent materials. In each case a weighted portion was treated with one of the solvents for 12 hours at room temperature. The data show that 0.1 N NaOH, while completely dissolving calcium humates and the organic part of alumo- and ferrous-humic compounds, destroys iron-humic compounds, converting a considerable part of the iron into hydrates. Its effects on aluminum hydroxide and on parent materials are just as destructive. As a result, a considerable part of the Al goes into solution. The 0.1 N H_2SO_4, which is usually used for decalcification, is highly decomposing of Al and Fe-humic compounds removing aluminum and iron. A considerable portion of these two elements is dissolved from parent material and non-silicate forms by 0.1 N H_2SO_4.

The effects of sodium pyrophosphate present a different picture. Quaternary sodium pyrophosphate ($Na_4P_2O_7 \cdot 10\ H_2O$, and $Na_4\ P_2O_7$ with molecular weights of 446 and 266, respectively) dissolves well in water (its solution has a weak alkaline reaction, pH 8-8.5). The $Na_4P_2O_7$, in completely dissolving all artificial preparations (humic acids, calcium humate, Al- and Fe-humic compounds), dissolves the organic portion in addition to the aluminum and iron.

An electrodialysis of the solutions demonstrated that Al and Fe remain in the anion part of the humic molecules. Only when the Al and Fe-humic preparations are extremely dehydrated, is there a small portion of the Al and Fe (2%-9%) which does not go into solution. At the same time, the $Na_4P_2O_7$ solution has no destructive effect on sesquioxide nonsilicate

Table 1

Effects of 0.1 N H_2SO_4 and NaOH and of 0.1 M $Na_4P_2O_7$ on preparations

Preparations		Dissolved, in percentages of the initial amount								
		0,1 N H_2SO_4			0,1 N NaOH			0,1 M $Na_4P_2O_7$		
		C	Fe_2O_3	Al_2O_3	C	Fe_2O_3	Al_2O_3	C	Fe_2O_3	Al_2O_3
Humic acid	1	3	—	—	100	—	—	100	—	—
	2	1	—	—	100	—	—	100	—	—
	3	0	—	—	95	—	—	100	—	—
Ca-humate	1	1	—	—	100	—	—	100	—	—
	2	0	—	—	100	—	—	100	—	—
	3	0	—	—	86	—	—	99	—	—
Al-humate	1	0	—	54	100	—	100	100	—	100
	2	0	—	38	100	—	100	100	—	100
	3	0	—	27	100	—	100	98	—	82
Fe-humate	1	0	62	—	100	69	—	100	100	—
	2	0	36	—	100	57	—	100	100	—
	3	0	15	—	100	40	—	91	94	—
$Fe(OH)_3$	1	—	19	—	—	0	—	—	0	—
	2	—	5	—	—	0	—	—	0	—
	3	—	3	—	—	0	—	—	0	—
$Al(OH)_3$	1	—	—	22	—	—	72	—	—	0
	2	—	—	18	—	—	65	—	—	0
	3	—	—	2	—	—	0	—	—	0

Remarks: 1 — fresh gel; 2 — dried at 30°C; 3 — dried at 100°C; Fe content in Fe-humate is 12%; Al content in Al-humate is 7%.

Note: Comma represents decimal point.

Table 2

Effects of 0.1 N H_2SO_4 and NaOH and of 0.1 M $Na_4P_2O_7$ on parent materials

Parent materials	Depth, cm	Dissolved, in mg per 100 g of parent material								
		0,1 N H_2SO_4			0,1 N NaOH			0,1 M $Na_4P_2O_7$		
		C	Fe_2O_3	Al_2O_3	C	Fe_2O_3	Al_2O_3	C	Fe_2O_3	Al_2O_3
Morainic non-carbonate clay loam	180	None	92	215	None	None	22	None	None	None
Fluvio-glacial sandy loam	160	11	76	171	"	"	80	9	"	8
Cambrian clay	260	None	12	32	None	None	19	None	None	None
Loess-like non-carbonate clay loam	180	40	320	975	21	"	164	27	"	17
Loess-like carbonate clay loam	220	37	272	189	21	"	152	19	"	14
Loess	190	39	237	224	20	"	32	21	"	9
Red-colored crust	260	None	42	114	None	"	600	None	"	8

ote: Comma represents decimal point.

ms, nor does it extract Al and Fe from ent materials. Only when the parent material contains some humic substances, is there a slight transfer of Al into solution, probably at the expense of Al-humic compounds.[1]

Footnote 1 on next page.

As we have found, the interaction between $Na_4P_2O_7$ and water-soluble calcium salts and carbonates produces water-insoluble $Ca_2P_2O_7$, which partially dissolves in excess pyrophosphate, forming a complex salt $(Ca_2P_2O_7)$ Na.

Calcium remains in the anion part of the molecule and is ionized only after acid hydrolysis. Because of this special property of sodium pyrophosphate, it is possible to use it to extract humic substances even from very extensively carbonated soils (sierozem), without first decomposing carbonates. Sodium pyrophosphate also forms pyrophosphates with water-soluble aluminum and iron salts. They dissolve only in excess sodium pyrophosphate, forming complex salts. Since soil usually does not contain water-soluble Al and Fe salts, this factor has no significance for the extraction of Al and Fe humic substances.

To learn the mechanism of $Na_4P_2O_7$ effects on soil humic sbustances, we studied solution concentration, interaction time, temperature, and soil:solution ratio on the humic substances obtained. Some of the data pertaining to these investigations are given in Figure 1. Extraction of humic substances proceeds fairly rapidly (2-3 hours) and additional time does not increase the total amount obtained. Temperature does not have any effect, either. Practically same quantities of humic substances were extracted at room temperature and when the temperature was increased to 100°C by means of a water bath. The ratio between soil and solution plays a role only when it is very narrow (1:5). Then the yield of humic substances noticeably decreases. As long as the sodium pyrophosphate concentration is 0.075 M or more, it has no effect. However, when it falls below this level, a sharp decrease in the yield of humic substances follows. As can be seen, the effects of 0.1 N NaOH on soil are quite different. In this case all of the factors substantially affect the yield of humic substances. All curves indicate a gradual hydrolysis of humic substances. Similar results we received by us for other soils.

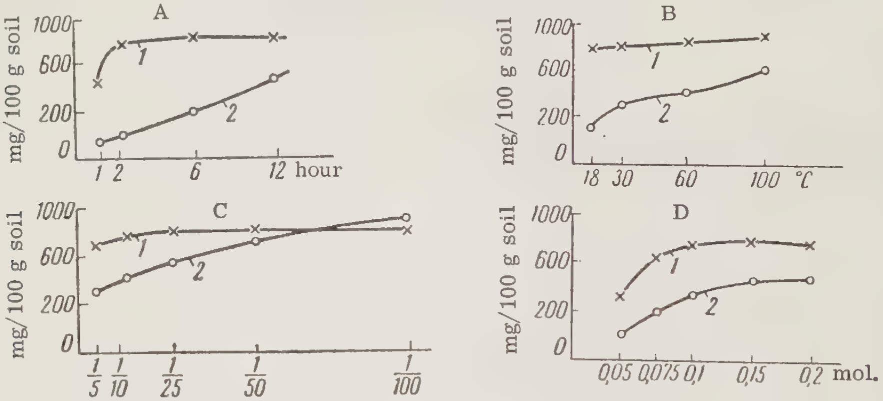

Fig. 1. - Yield of humic substances from chernozem (0-10 cm) in pyrophsophate extract.

A - time effect; B - temperature effect; C - effect of soil-solution ratio; D - effect of concentration. 1 - 0.1 N $Na_4P_2O_7$; 2 - 0.1 N NaOH.

Our investigations permit us to assume that the mechanism of the action of $Na_4P_2O_7$ upon humic substances amount to an irreversible substitution reaction between cations, resulting in the formation of soluble humic, Al and Fe humic salts. Their formation proceeds as follows:

1. $R(COO)_4Ca_2 + Na_4P_2O_7 \rightarrow R(COONa)_4 + \downarrow Ca_2P_2O_7$

2. $2[RCOOFe(OH)_2](COO)_2Ca + Na_4P_2O_7 \rightarrow 2[RCOOFe(OH)_2](COONa)_2 + \downarrow Ca_2P_2O_7$

3. $2[RCOOAl(OH)_2](COO)_2Ca + Na_4P_2O_7 \rightarrow 2[RCOOAl(OH)_2](COONa)_2 + \downarrow Ca_2P_2O_7$

Owing to the formation of water-insoluble $Ca_2P_2O_7$, the reaction proceeds in one direction only and fairly fast.

The isolated Al and Fe humic compounds are easily hydrolyzed with hydrochloric acid. They are converted into chlorides and the excess sodium pyrophosphorate changes into orthophosphate.

Table 3 gives some data on the quantities of Al and Fe which go into sodium pyrophosphat solution. As has been already pointed out, 0.1 N NaOH extracts practically no Fe. The quantity of Al that goes into solution varies considerably and probably depends on the duration of the interaction between the soil and the alkaline solution.

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[1] It should be noted that $Na_4P_2O_7$ causes considerable peptization of the clay and colloid fractions. Therefore it is necessary to use coagulators (K_2SO_4, Na_2SO_4).

Table 3

Amounts of C, Fe_2O_3 and Al_2O_3 extracted from soil by 0.1 M $Na_4P_2O_7$

Soil	Depth, cm	In mg/100 g of soil			Soil	Depth, cm	In mg/100 g of soil		
		C	Al_2O_3	Fe_2O_3			C	Al_2O_3	Fe_2O_3
Chernozem	0—10	1153	232	120	Podzolic	5—9	666	159	169
	20—30	954	261	101		9—22	112	50	69
	40—50	769	262	88		41—61	48	45	86
	78—88	319	102	61		110—120	14	None	13

It is a much more complicated problem to ermine which part of the humic substances extracted from the soil by 0.1 M $Na_4P_2O_7$. ble 4 gives some comparative data on the ıntitative and group composition of humic ostances extracted from soil either by pyro- osphate, or by the commonly used Tyurin thod of fractional analysis. As the data icate, direct pyrophosphate treatment yields out 70% of the total humic substances pro- ced by the ordinary method (for sierozem out 60%). Additional treatment of soil with N H_2SO_4 is not very effective. Humic sub- nces thus added to the pyrophosphate extrac- ı do not exceed 1.5%-5% of their original ntity.[2] It may be assumed that this amount carbon comes primarily from the acid hy- lysis of several already semi-humic organic idues. It is especially important to note t this decreased yield of humic substances caused by the fulvic acid group. The most iking example of this is furnished by cher- em, where direct alkaline extraction pro- es twice as much fulvic acid. The amounts numic acid, when extracted by the pyrophos- te method alone or when followed by 0.1 N O_4 and NaOH, are almost the same for all ls (chernozem, 21.9 and 23.1; podzolic soil, 1 and 10.9; red earths, 8.4 and 9.2; siero- n, 8.7 and 10.3). The high yield of fulvic d, lasting sometimes for several days dur- the follow-up treatment of a weighed por- ı with alkali and acid, can be explained by ımber of reasons. The alkaline treatment ults in partial hydrolysis of the humic acids nselves. Special experiments have corrob- ted this assumption.

Table 5 shows the amounts of humic and ic acids extracted by $Na_4P_2O_7$ from humic stances before and after their treatment NaOH up to pH 10-12.

Continuous hydrolysis by acid and alkali also causes the separation of a certain portion of the organic substances contained in semidecomposed residues. And it is a well-known fact that 0.1 N Na_2SO_4 and NaOH extract a considerable amount of carbon even from undecomposed vegetative residues. Finally, the acid treatment increases the yield of fulvic acids by acting on that part of them which is firmly bound to old and extensively dehydrated iron oxides. Thus, it may be assumed that the direct treatment of soil with pyrophosphate extracts "purer" humic substances; free ones, as well as those that form the upper part of films on various inorganic fractions. That portion of the humic substances which has become firmly bound to the surface of minerals cannot be extracted either by $Na_4P_2O_7$ or by 0.1 N NaOH even when the soil is first treated with 0.1 M H_2SO_4. Only an alternate treatment of soil with stronger solutions results in a gradual release of a certain part of such substances. After humic substances have been removed from soil by 0.1 N NaOH and H_2SO_4, an additional treatment with sodium pyrophosphate extracts practically none of the humic substances firmly bound to the mineral part of the soil. Thus, for instance, an experiment with such a follow-up pyrophosphate treatment of various soils added only the following amounts of C, expressed as percents of initial content: chernozem (0-10 cm), 1.7%; podzolic soil (2-9 cm), 0.9%; red earth (0-10 cm), 0.7%; and sierozem (0-10 cm), 0.5%. It should be noted that, when sodium pyrophosphate is used, we obtain a more characteristic humic acid:fulvic acid ratio for each soil group. This ratio is highest for chernozem, which has the most favorable conditions for humic acid synthesis. It is lowest for red earths, because of the intensity of the hydrolytic breakdown of organic residues.

The optical density of humic acids extracted by means of sodium pyrophosphate and a follow-up treatment with 0.1 N H_2SO_4 and NaOH from chernozem and podzolic soils is practically the same, provided that the same pH is maintained. Direct treatment with 0.1 N NaOH produces humic acid with the lowest optical density. Fulvic acids contained in pyrophosphate extracts from podzolic soils have a higher optical density (Fig. 2). It appears that alternate acid-alkali treatment penetrates deeper into the whole unstable humic-substance

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should be noted that preliminary soil treatment 0.1 N H_2SO_4 while not increasing substantially ield of humic substances, leads to a sharp in- se in Al and Fe, which enter the pyrophosphate act because of the decomposition of the mineral of the soil by sulfuric acid. Therefore, $Na_4P_2O_7$ ot be used to extract aluminum- and iron-humic ounds after the soil has been treated with sul- acid.

Table 4

Amount of humic substances and their chemical-group composition in various soils (C in percentages of total content)

Soil	Depth, cm	Total C, %	Solvent	Directly				0,1 N H_2SO_4	Following 0.1 N H_2SO_4				Total			
				Total	Of humic acids	Of fulvic acids	humic acids / fulvic acids		Total	Of humic acids	Of fulvic acids	humic acids / fulvic acids	Total	Of humic acids	Of fulvic acids	humic acids / fulvic acids
Chernozem	0—10	4,04	$Na_4P_2O_7$	28,5	21,9	6,6	3,3	1,6	4,8	2,3	2,5	0,9	34,9	24,2	10,7	2,3
			NaOH	19,9	7,3	12,6	0,6	2,0	20,4	15,8	4,6	3,5	42,3	23,1	19,2	1,2
Podzolic	2—9	2,70	$Na_4P_2O_7$	24,7	10,1	14,6	0,7	4,0	2,1	0,6	1,5	0,4	30,8	10,7	20,1	0,5
			NaOH	28,2	8,6	19,6	0,4	3,2	4,1	2,3	1,8	1,3	35,5	10,9	24,6	0,4
Red earths	0—10	3,56	$Na_4P_2O_7$	24,9	8,4	16,5	0,5	4,4	1,5	0,4	1,1	0,4	30,8	8,8	19,1	0,5
			NaOH	24,5	7,5	17,0	0,4	5,1	4,3	1,7	2,6	0,7	33,9	9,2	24,7	0,4
Sierozem	0—10	0,76	$Na_4P_2O_7$	15,3	8,7	6,6	1,3	Not det'd.[a]	4,9	1,7	3,2	0,5	20,2	10,4	9,8	1,0
			NaOH	15,6	5,5	10,1	0,5	"	11,5	4,8	6,7	1,0	27,1	10,3	16,8	0,7

[a] Decalcified by 0.5 N HCl and then by 0.1 N H_2SO_4.

Note: Comma represents decimal point.

Table 5

NaOH effect on composition of humic substance

Soil	C in mg/100 ml of solution			
	Before NaOH treatment		After NaOH treatment	
	Humic acids	Fulvic acids	Humic acids	Fulvic acids
Chernozem	50,3	20,1	45,1	25,0
Podzolic	18,2	25,1	10,9	32,2

Note: Comma represents decimal point.

system of podzolic soil. It should be noted that the pH of the solution has a great effec on the optical density. This is especially true in the case of the fulvic acid group, regardless of the method used to isolate them The greater the pH, the higher the optical density (Fig. 3). Therefore, to be meaningful, each optical density must include the p

In conclusion, we should briefly dwell on the method of determing Al and Fe in alumi and iron-humic compounds extracted by sod um pyrophosphate. Our investigations demo strated that some of the sesquioxides break even when the humic acid is precipitated, ar a certain amount remains in the precipitate this acid. Because of the presence of exces sodium pyrophosphate, their determination i made even more difficult. For best results a 30-40 minute hydrolysis in a 5% hydrochlo acid solution should be used. During the hyd lysis, Al and Fe are removed completely an converted to chlorides, while t e excess hyd phosphate changes into orthophosphate. The quantitative precipitation from the orthophos phoric acid solution can be achieved with ammonium hydroxide. Analysis of the precipitate showed that all the Al and Fe precipi tated orthophosphates ($AlPO_4$ and $FePO_4$). In many cases Ca, released from a complex sodiu pyrophosphate salt during acid hydrolysis, becomes a part of the precipitate as $Ca_3(PO_4)_2$. The quantity of Al and Fe is determined colo metrically. In the case of iron, good results are achieved with ammonium rhodanate and salicylic acid. Aluminum can be most accurately determined with hydroxyquinolime. This method, however, is technically very co plicated. The colorimetric method with aluminum can be used, provided one remains within that portion of the scale which distinct shows the coloring proportionality. The amo of Al can be also calculated by difference, but in this case allowance for calcium must be made.

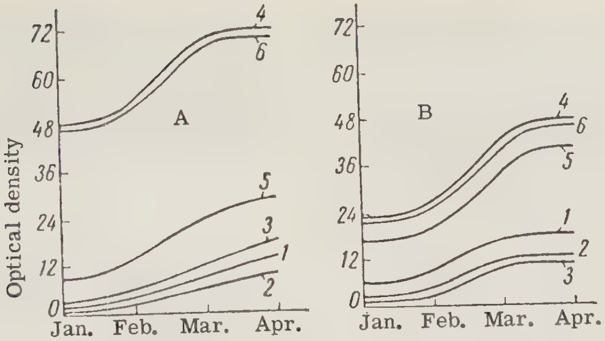

Fig. 2. - A - Optical density of chernozem humic substances, pH5; and B - podzolic-soil humic substances, pH 5.

Light filters: I - red; II - orange; III - green; IV - blue. Fulvic acids: 1 - 0.1 M $Na_4P_2O_7$; 2 - 0.1 N NaOH; 3 - 0.1 N H_2SO_4 + 0.1 N NaOH; Humic acids: 4 - 0.1 M $Na_4P_2O_7$; 5 - 0.1 N NaOH; 6 - 0.1 N H_2SO_4 + 0.1 N NaOH.

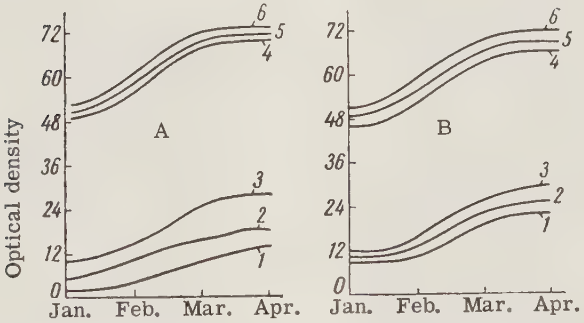

Fig. 3. - Effects of pH on optical density of chernozem humic substances (0-10 cm). A - extracted by 0.1 M $Na_4P_2O_5$; B - extracted by 0.1 N NaOH after decalcification with 0.1 N H_2SO_4.

Light filters: I - red; II - orange; III - green; IV - blue. Fulvic acids: 1 - pH 5; 2 - pH 7; 3 - pH 10. Humic acids: 4 - pH 5; 5 - pH 7; 6 - pH 10.

The analysis proceeds as follows: A 5-20 g soil sample is placed in an Erlenmeyer flask and treated with 200-500 ml of freshly prepared 0.1 M $Na_4P_2O_7$ at room temperature[3] (the larger the humic content of soil, the smaller the soil sample and the wider the ratio of soil to solution). A few K_2SO_4 crystals are added to coagulate organic-mineral colloids. Extraction of the humic substances requires 2-3 hours (can be left overnight). The settled solution is processed through a centrifuge or a dry filter. Afterwards a membrane filter or a bacteriological candle is used to eliminate colloids. Tyurin's method is used to determine the total carbon and the quantity of humic acids in individual portions of the filtrate. These acids are precipitated from 20-50 ml filtrate portions into methyl orange (drop test on filter paper) by means of a 20% H_2SO_4 solution until the filtrate has been decolorized. Then it is dissolved in an $NaHCO_3$ solution[4] in a clean 50-100 ml volumetric flask. The total carbon in the individual portions is once again determined by Tyurin's method. The fulvic acid carbon is determined by difference. (As a double check it is advisable to determine the fulvic acid carbon in the sulfate filtrate after the humic acids have been precipitated). The quantities of humic and fulvic acids are calculated in milligrams per 100 g of soil. Depending on the soil group, the following coefficients are used for this purpose: 1.7 or 1.85 for humic acids, and 2.0 or 2.2 for fulvic acids.[5]

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[3] When the solution is kept for a long time, sodium pyrophosphate partially changes into orthophosphate. The solution should produce pale-pink coloring when phenolphtalein is added.

[4] The humic acid precipitate is peptized very fast when washed with water.

The amount of Al and Fe is determined as follows. A 7-10 ml portion of 5% HCl (free of Fe^{++}) is added to 50-75 ml of the solution. Then the solution is boiled under a reflux consenser for one hour. If the HCl does not produce humic acid flakes and the solution remains colorless, a few glass capillaries should be installed in the flask to prevent overheating of the solution in the course of hydrolysis. During the acid hydrolysis Al and Fe are converted to chlorides and the excess pyrophosphate changes to orthophosphate. To remove the sodium pyrophosphate excess and the organic substances, the hydrolyzate is filtered and washed with 1% HCl solution showing a negative reaction for Fe^{++}. The resultant HCl acid solution is treated first with 25% and then with 10% NH_4OH to precipitate Al and Fe. These minerals settle as pale-yellow or white flakes, usually contaminated with organic substances.[6] The solution and its precipitate are then heated and boiled until the odor of ammonia has been completely eliminated. Then it is filtered through a loose ash-free filter, washed two or three times with hot 0.5% $NaNO_3$, and heated strongly in a porcelain crucible to eliminate organic matter. After cooling, the precipitate in the crucible is dissolved in 1-2 ml of concentrated HCl, while being heated on a hot plate in a hood. Then it is dissolved in water and filtered into a 50 ml volumetric flask. The filter is washed with hot water containing a small amount of HCl until a negative Fe^{+++} reaction is registered. The amounts of Al and Fe are determined colorimetrically. Their content is calculated in terms of Fe_2O_3 and Al_2O_3 and expressed in milligrams per 100 g of soil. The amount of Al can also be calculated by difference. In this case a 3-5 ml portion of 1 n Na_3PO_4 is added to the hydrochloric acid solution containing the Al and Fe, and R_2O_3 is once again precipitated with ammonium hydroxide. The precipitate is passed through a loose ash-free filter, washed with hot 0.2% $NaOH_3$ until it shows a negative Cl^- reaction, heated to constant weight, and weighed. Then the precipitate is dissolved in concentrated HCl in the same way as described previously. A portion of the filtrate is used to determine Fe and the rest of it (30-40 ml) is used to determine calcium. In order to do this, sesquioxides are again precipitated by ammonia, heated to the boiling point, dissolved by adding a few oxalic acid crystals until a clear acid reaction is shown with methyl red. Should there be a $Ca_2C_2O_4$ precipitate, the solution is boiled for two or three minutes and the amount of calcium is determined volumetrically. After the $Ca_3(PO_4)_2$ and $FePO_4$ contents have been calculated, the amount of $AlPO_4$ is determined by difference and expressed in terms of Al_2O_3 by conversion.[7] The weight ratio between hum and fulvic acids, on the one hand, and R_2O_3 on the other, indicates the degree of saturation of humic substances with Al and Fe. This metho is designed for mineral soils.

Conclusions

A method for determining humic substances and their complex aluminum and iron salts not bound firmly to the mineral part of the soil has been suggested. The use of 0.1 M $Na_4P_2O_7$ is recommended for this purpose. The amounts of humic and fulvic acids in the extract are determined first, and the aluminum and iron contents are determined after acid hydrolysis has taken place.

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[5] When the elementary content of humic substances in a soil under study is unknown, the coefficient is determined on an experimental basis by first adopting a 1.78 average value for humic acids and 2.1 average value for fulvic acids.

[6] The methyl-red indicator is very convenient in precipitating R_2O_3.

[7] Conversion coefficients: Ca into $Ca_3(PO_4)_2$ — 2.58; Fe_2O_3 into $FePO_4$ — 1.81; Al PO_4 into Al_2O_3 — 0.418.

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QUICK AND SIMPLE ELECTROMETRIC METHOD FOR DETERMINING SULFATE IN SALINIZED SOILS

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The determination of soluble soil sulfates is very important in establishing the degree of salinization of soils. Most frequently (1) soil sulfate ions are determined as barium sulfate gravimetrically. This is a very tedious and time-consuming method, requiring 10-12 hours. In addition, when applied to soil, this method involves equally laborious preliminary operations, including the preparation of a water extract (removal of fine suspended material, colloidal particles, etc.).

The electrometric method of determing sulfates developed by one of the co-authors of this paper (2) does not have these defects. Sulfates can be determined within a few minutes; no water extraction is needed; and the determination can be made either in the laboratory or in the field.

The electrometric method is based on the principle that a platimum wire ferri-ferrocyanide electrode submerged in a solution of $K_3Fe(CN)_6$ and $K_4Fe(CN)_6$ reacts to changes in lead-ion concentration. Thus this electrode can be used as an indicator in titrating sulfate ions by lead nitrate. The ferri-ferrocyanide electrode potential is determined by the following equation (4).

$$E = E_0 + \frac{RT}{nF} \ln \frac{[Fe(CN)_6^{3-}]}{[Fe(CN)_6^{4-}]} \qquad (1)$$

The reaction between lead ions and ferrocyanide is expressed by the following equation:

$$2Pb^{2+} + Fe(CN)_6^{4-} = Pb_2Fe(CN)_6,$$

and therefore, according to the law of mass action:

$$[Fe(CN)_6^{4-}] = \frac{SP_{pb_2Fe(CN)_6}}{[Pb^{2+}]^2}, \qquad (2)$$

where SP is the solubility product.

Using the ferrocyanide value from Equation (2) and assuming the ferrocyanide concentration to be constant, we can rewrite Equation (1) as follows:

$$E = E_0' + \frac{2RT}{nF} \ln [Pb^{2+}], \qquad (3)$$

where

$$E_0' = E_0 + \frac{RT}{nF} \ln \frac{[Fe(CN)_6^{3-}]}{SP_{Pb_2Fe(CN)_6}} \qquad (4)$$

It follows from Equation (3) that the ferri-ferrocyanide potential reacts to changes in lead ion concentration in the solution.

Thus, titration of a sulfate solution containing a constant or small (specified) amount of ferrocyanide with lead nitrate would actually change the indicator electrode potential very little before complete sulfate precipitation. But as soon as all sulfate has been precipitated, the excess lead ions would sharply change the ferri-ferrocyanide concentration ratio (because of $Pb_2\,Fe(CN)_6$ precipitation). As a result, the potential would increase sharply, indicating the equivalent point of titration.

N. A. Ugol'nikov and D. Ye. Galkin (5) have established that, when 1 ml of 0.1 M $K_3Fe(CN)_6$ and 0.1 ml of 0.005 M $K_4Fe(CN)_6$ are added to 30-50 ml of the sulfate solution under study, a sharp increase in the ferri-ferrocyanide electrode potential occurs at the equivalent point and reaches its optimum. They also established that sulfate titration with lead nitrate should be carried out in a water-alcohol medium, with an alcohol concentration at the end of titration of not less than 30%. Otherwise, the increase in the potential would be insignificant and hard to detect. The titration is not sucсussful in a water medium.

The equivalent point can be registered by the potentiometric method (4, 3). However, most simple and convenient for this purpose is the electrometric method employing pairs of bimetal electrodes, in particular the platinum-silver pair (2). It takes advantage of the fact that the platinum electrode potential changes four times as fast as the silver when the concentration ratio of ferri- and ferrocyanides changes to the same degree. Therefore, there occurs at the titration equivalent point a sharp increase in the E. M. F. of the platinum-silver galvanic cell, which is easily recorded by a galvanometer.

Water extracts were prepared from several soil samples to verify the applicability of the electrometric method for determining the ulfate salinization of soils in the following nanner (1):

First the soil was ground and sifted through sieve with 1-mm opening. Then 100g of the oil (dry weight) was put into a 1-liter wide-nouth glass bottle. Five times as much (500 nl) distilled water was added; the bottle was toppered and shaken for five minutes. The nixture was then passed several times through he same paper filter until the filtrate became ompletely transparent and thus suitable not nly for the electrometric method, but also for he gravimetric method. The latter was used n determining sulfate ions for purposes of omparison. For the electrometric method tself it is not necessary to have a completely lear solution.

From 20 to 50 ml (depending on sulfate conent) of this extract were transferred by pipette o a 100-150 ml titration beaker. Sufficient itric acid was added as in methyl orange tests o assure complete decomposition of carbonates nd prevention of lead carbonate precipitation. f the carbonate content is high, it may be adisable to boil the acidified solution. A large xcess of acid should be avoided and the pH of he solution should not be less than 3, since vith increased acidity the EMF jump is less oticeable.

After the elimination of carbonates, the eaker was filled with 1 ml of 0.1 M $K_3Fe(CN)_6$, . 1 ml of 0.005 M $K_4Fe(CN)_6$, and 20-50 ml an equivalent volume(of 96% ethyl alcohol. ext a pair of platinum-silver electrodes, conected with the galvanometer through a high-hm resistance (as shown in Fig. 1), was nserted into the glass and an electric mixer vas turned on. The titration was carried out y adding a 0.1 N lead nitrate solution coninuously from a burette by drops (at the end of itration the rate should be approximately one rop per second), until the first noticeable novement of the galvanometer needle (EMF ump) indicates the equivalent point. The tiration was repeated twice: the first time to etermine the approximate amount of lead itrate needed, and the second time to deternine the exact amount used. Our calculations vere based on the data provided by the second itration.

The lead nitrate solution titer was deternined with a sodium sulfate solution of known oncentration. The electrometric method was sed for this purpose under the titration conitions described. The Pb $(NO_3)_2$ solution iter can be determined by a standard aqueous olution containing a known content of sulfate for instance, as determined by the gravimetric nethod). Such a solution can be kept a long me as a standard for the lead nitrate working olution.

Any galvanometer with a sensitivity of 10^{-6} mp or higher can be used to register the hange in the EMF. When a very sensitive alvanometer is used, such as a mirror galanometer (shunted so as to keep the lightbeam ithin the scale during the titration process), e equivalent point can be determined, not by e first needle movement, but by the titration urve or by the second derivative $\Delta i/\Delta v$ (1 - galvanometer reading), as is usually done in potentiometry (3). Of course, these two methods are more precise. However, in most cases needle-type galvanometers produce satisfactory results. One should only follow the same routine in first setting up the lead nitrate and then working with the water extracts being analyzed. Care should be taken.

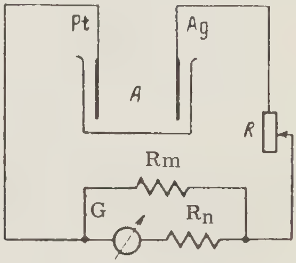

Fig. 1. — Functional diagram of the electrometric device.

A - titration vessel; Pt - platinum electrode; AG - silver electrode; R - High-ohm resistance (for a mirror galvanometer - 1.5-3.0 M ohm; for a needle-type galvanometer - 30-50 k ohm); Rm Rn - galvanometer shunt (not used with a needle-type galvanometer); G - galvanometer.

A semiconductor or potentiometer, as commonly used in electronics, is quite suitable as the high-ohm resistance. During titration the galvanometer needle (or lightbeam) remains almost motionless until the equivalent point is reached, at which time it makes a sharp movement (jump).

During our experiments, the silver electrode became covered with a white film consisting mostly of $Ag_4Fe(CN)_6$. This does not interfere with titration (2) and no special cleaning is required. Only when this film becomes dark in color should it be removed by means of fine sandpaper. After each titration the electrodes should be rinsed in distilled water. The electrodes can be made of thin platinum and silver wire (1 mm in diameter) or small plates.

Table 1 shows the results with the electrometric and gravimetric methods involving ten soil samples. As can be seen, the electrometric method, while being accurate enough for practical purposes, reduces the time required to 10-12 minutes.

Conclusions

A rapid and simple method for determining sulfate salinization of soils has been developed. By using this method, it is possible to determine

Table 1

Soil Sample No.	Sulfate ions found, %		Deviation in % (absolute)	Soil Sample No.	Sulfate ions found, %		Deviation in % (absolute)
	gravimetric method	electrometric method			gravimetric method	electrometric method	
1	0,25	0,29	+0,04	6	0,32	0,36	+0,04
2	0,50	0,55	+0,05	7	0,21	0,23	+0,02
3	0,84	0,86	+0,02	8	0,15	0,17	+0,02
4	0,56	0,57	+0,01	9	0,30	0,33	+0,03
5	0,42	0,41	−0,01	10	0,25	0,27	+0,02

Note: Comma represents decimal point.

sulfates in a few minutes and with a degree of accuracy sufficient for practical purposes.

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A RAPID AND ACCURATE METHOD OF DETERMINING THE ADSORPTION CAPACITY OF CALCAREOUS SOILS

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Degree of solonetzization is one of the most mportant factors to be considered in establishng effective and rational methods of improvenent and subsequent control of solonetz and olonetzic soils. It is a well-known fact that his degree varies considerably even among soils ightly classified as solonetz because of their istinctly pronounced solonetzic profiles. Solonetzization of this soil group is determined by onditions of genesis. By its degree we undertand the ratio (in percentages) between exchangeble cations. The latter is equivalent to the adorption capacity and is usually expressed in neq per 100 g of completely dry soil. Thus, to stablish degree of solonetzization, one must irst determine exchangeable sodium and soil dsorption capacity (the latter is easier and impler to do than to determine separately each f the exchangeable cations). This has been one by means of either the special or the genral method suggested by K. K. Gedroyts.

As these methods are cumbersome and laborous, we have been trying to find a simpler, ut equally accurate, new method. In doing so, e tested the following method[1] in its practical pplication.

Adsorption capacity determination by means f Pfefer's method. Place 10 g of soil into a Erlenmeyer flask, add 25 ml of displacing soluon, shake well two to three[2] times within one our, and leave it to stand overnight. Next norning process the solution through small lters, while covering funnels with a piece of lass, and then wash thoroughly five times ith 15 ml-portions of the same displacing soluon.

This displacing solution is prepared as folows: dissolve 5.35 g of ammonium chloride n 315 ml[3] of water, add 665 ml of 96-percent alcohol, carefully add, drop-by-drop, ammonium hydrate until the pH reaches 7.

Pipette 25 ml of the prepared solution, heat it to the boiling point, add 5 ml of formaldehyde (35%) and a few drops of phenolphthalin, and titrate it with 0.1N sodium hydroxide. While doing this, heat the solution once more and then complete the titration. Use a pipette to take 50 ml of the filtrate from treated soil and titrate it in the same way.

Adsorption capacity would be expressed, in meq per 100 g of soil, as follows: (A x 2) — B· 2, where A is the amount of 0.1N NaOH, in ml, used to titrate 25 ml of the original solution; and B is the ml of 0.1N NaOH amount, used to titrate 50 ml of the filtrate after the soil has been treated.

Pfefer's method is based on the principle of displacing all exchangeable soil cations by ammonium (NH_4) contained in the water-alcohol (1:2) 0.1 N NH_4Cl. The amount of ammonium left over after the exchange reaction is determined by an indirect method. After treating and leaching soil with NH_4Cl solution, a certain amount (two 25 ml doses) of the resultant filtrate is titrated with 0.1 N NaOH in the presence of formaldehyde. We already know the total ammonium content in a corresponding amount of the water-alcohol NH_4Cl solution. Therefore, by determining its remaining content in this amount of the filtrate, we can find out how much NH_4 was used to replace cations of the soil exchangeable complex.

The essence of these reactions can be outlined as follows:[4]

1. $\boxed{SAC}\ M + NH_4Cl = \boxed{SAC}\ NH_4 + MCl_2 + NH_4Cl$
2. $4NH_4Cl + 6HCOH \rightarrow (CH_2)_6N_4 + 4HCl + 6H_2O$
3. $4HCl + 4NaOH = 4NaCl + 4H_2O.$

These reactions (Equation 2) show that for each 1 meq of the excess ammonium there is 1 meq of HCl formed as a result of the reaction

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[1] Suggested by K.V. Verigina (V.V. Dokuchayev oil Science Institute, USSR Academy of Sciences).

[2] Shaking (rocking) was done by an automatic rotator r one hour.

[3] We increased the amount of water from 315 ml to 35 ml in order to have one full liter of the water-cohol ammonium chloride solution.

[4] SAC — soil adsorption complex; M — exchanged cations (Ca, Mg, Na); NH_4Cl — left over after the exchange of SAC cations; $(CH_2)_6N_4$ — urotrapine or hexamethylene tetramine formed by the reaction between formaldehyde and NH_4Cl.

Table 1

Comparative results of Pfefer's and Gedroyts' methods used concurrently to determine adsorption capacity

Profile No.	Soil group	Depth, cm	Adsorption capacity by Pfefer		Adsorption capacity by Gedroyts		± deviation from standard	
			%	meq	%	meq	%	meq
2	Solonetz, deep plowed	0—20	0,416	18,1	0,364	16,7	+8,4	+1,4
		20—40	0,727	31,6	0,727	31,6	0	0
		40—60	0,697	30,3	0,697	29,6	+2,3	+0,7
6	Solonetz, deep plowed	0—20	0,444	19,3	0,333	14,5[a]	—	—
		20—50	0,414	18,0	0,414	18,0	0	0
		50—68	0,522	22,7	0,544	23,7	—4,2	—1,0
		68—90	0,478	20,8	0,524	22,8	—8,7	—2,0
9	Solonetz, deep plowed	0—20	0,469	20,4	0,494	21,5	—5,1	—1,1
		20—38	0,533	23,6	0,550	23,9	—1,2	—0,3
		38—65	0,465	20,2	0,476	20,7	—2,4	—0,5
	Solonetz horizon B	Sample 1	—	—	0,545	23,7	—	—
		Sample 2	—	—	0,563	24,5	—	—

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[a] Eliminated from comparison. Because the filter was loose, leaching occurred too fast causing incomplete saturation of the exchangeable complex with sodium.

Note: Comma represents decimal point.

between NH_4Cl and formaldehyde. If we titrate hydrochloric acid with 0.1N NaOH, we would indirectly establish the amount of ammonium left out of the exchange reaction.

Now we know the exact amounts of ammonium in a volume unit (25 ml) of the water-alcohol (1:2) ammonium chloride solution and in a volume unit (50 ml) of the filtrate after the soil has been treated. By substituting these values for the latter symbols in the summarized formula given, we can calculate the soil adsorption capacity in meq per 100 g.

The results of a parallel application of Gedroyts' and Pfefer's methods in determining soil cation-exchange capacity are given in Table 1. Nine samples of solonetz soils from the Sivash coastal-area, Crimean Region, were used for this purpose. In most cases a satisfactory agreement was observed. Only in two cases — Profile 2, 40-60 cm-layer; and Profile 6, 68-90 cm layer — deviations from the standard (Gedroyts' method) amounted to +8.4% and -8.7%, respectively. Deviations for other seven samples did not exceed ± 5%, i. e., they were within the limits of possible discrepancy when making two determinations of the same sample by the same method (solonetz, B horizon).

Adsorption capacity of soil samples can be determined in one working day, as an average, when Pfefer's method is used. This is five to six times faster than Gedroyts' general method. The latter method, because of the time-consuming process involved (1.0 N NaCl solution treatment of soil samples to achieve sodium saturation), requires at least 48 hours to produce final results. Pfefer's method, on the other hand, produces them already on the next day.

On the basis of our findings, we recommend Pfefer's method to be used for practical purposes because of the considerable speed and sufficient accuracy.

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A PHOTOMETRIC METHOD OF DETERMINING TOTAL PHOSPHORUS IN SOIL

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Determination of total phosphorous content in the soil involves laborious chemical analyses. According to K. K. Gedroyts, Nissens' method is the simplest and most dependable of the many gravimetric and volumetric methods described in the literature (3). But Nissens' method has certain substantial defects, principally the following:

1. The composition of the yellow phosphorus-molybdenum heteropoly-complex formed during the analysis by the interaction between phosphorus and molybdenum ions, is very variable. Its composition and rate of formation depend to a great extent on the composition of the soil extract, the temperature of precipitation, the amount of phosphorus in the solution, and other factors (1, 3, 4). This means that the accuracy of Nissens' method of determining total phosphorous content can be assured only when many physiochemical factors are taken into consideration; this is very troublesome in large-scale soil analyses.

2. Because of the large titration error, this method is not advised for determining small amounts (less than 1 mg) of phosphorus.

3. This method is very tedious and consumes considerable quantities of time and materials.

All of this prompted us to investigate the possibility of using for this purpose a method of determining total phosphorous content which would be more convenient and free from the defects of the known gravimetric and volumetric methods.

For this purpose we used a photometric method of phosphorous determination from the blue phosphorus-molybdenum heteropoly complex with sulphite and a salt of divalent iron as reducing agent (1, 2).[1] This method makes it unnecessary to precipitate the phosphoric acid contained in the soil extracts. Thus, it assures more accuracy and greatly shortens the time required for analysis by Nissens' method.

The use of this method for determining total phosphorus involves the following three operations: a) making the soil extract; b) preparing the extract for analysis; and c) photometry.

The soil extract is prepared in the following way (with the commonly used method of "wet" combustion of the soil sample). Ten grams of soil is sieved through a 1-mm opening sieve and placed in a 250 ml Kjeldahl flask. 2 ml of sulfuric acid (specific gravity 1.84) and 40 ml of nitric acid (specific gravity 1.40) are poured in slowly. The flask is then placed on a sand bath and the contents heated to slow boiling. At this temperature the "wet" combustion takes three hours. When the oxidation is finished, the contents are diluted with 50 ml of hot distilled water and then filtered through a specially prepared double filter[2] into a 250 ml volumetric flask. The residue on the filter is washed repeatedly with boiling distilled water until all trivalent iron is gone (potassium thiocyanide test). At the same time the Kjeldahl flask is rinsed several times with small amounts of hot water until the test for trivalent iron is negative. All the rinses are added to the same volumetric flask. The contents of the flask are cooled to room temperature and brought up to volume with distilled water.

The following procedure is followed in preparing the soil extract for analysis. A 25 ml portion of the extract is transferred by a pipette into a 50 ml porcelain dish and evaporated under a hood to eliminate the nitric acid. The residue is wet with ten drops of concentrated sulfuric acid, and 8-10 ml of distilled water are added. The dish is then heated for 5-10 minutes in a water bath to dissolve the residue more fully. The quantity of solution thus obtained is then transferred through a funnel into a 50 ml volumetric flask. The dish and the stirring rod used are rinsed with small portions of distilled water and the rinse water is added to the solution in the volumetric flask. The contents of the flask are brought up to volume with distilled water, shaken, and filtered. Two millimeters (or any other number) are added with an accurately graduated pipette to a 50 ml Erlenmeyer flask. Four ml of a solution of iron-ammonium alum[3] is added to the flask and then dilute ammonia (1:1) is introduced drop-by-drop until the iron hydroxide has precipitated. The precipitate formed is dissolved in a few drops of 4-N hydrochloric acid and a 2 ml excess of the latter is added. Then 4 ml of a 20% sulfite solution is added and the contents are boiled for one minute to reduce the iron. During this process the yellow or yellow-cinnamon-brown color of the solution almost disappears.

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[1] This reducing agent is recommended by the GOST 2331-43 for photometric determination of phosphorus n steel and cast iron.

[2] The filters are prepared by treating with 1% hydrochloric acid (to eliminate substances soluble in the acid) and washed with distilled water until they show a negative reaction for chlorine ion (silver nitrate test).

If, after heating, the solution retains a greenish-yellow color, this means that the iron has not been fully reduced because of excess acidity. In this case a few more milliliters of the sulphite solution must be added and the solution heated. On the other hand, when there is not enough acid, the solution has a gold hue. To remove the color it is necessary to add a few more drops of 4N hydrochloric acid and again heat to boiling.

The solution is then cooled, and 6 ml of 4N hydrochloric acid is added. Then, while the flask is being shaken, 4 ml of a 5% solution of ammonium molybdate is added drop-by-drop. The solution is added quantitatively to a 50 ml volumetric flask, the liquid in the flask is brought up to volume with distilled water, shaken, and is then ready for photometry.

The ordinary method is followed in plotting the calibration graph for the relationship between light absorption and P_2O_5 concentration in the solutions studied (2). The control ("blank") solution contains all reagents involved except for the phosphorus being determined.

The photometric analysis, that is, the measurement of the light absorption of the phosphorus-molybdenum blue heteropolyacid solutions under study, can be done with the SF-4 (λmax = 825 mμ) spectrophotometer; the FM, FM-58, or FMS photometers, the FEK-M, FEK-N-57, or FEK-56 photoelectric colorimeters using red filters.

Figure 1 presents a sample set of calibration curves for phosphorus molybdenum heteropolyacid solutions reduced by sulphite and divalent iron salts. The curves were plotted from readings of an FEK-M photoelectric colorimeter.

The readings of the photometric instrument are used to find the P_2O_5 concentration in 50 ml of solution on the calibration curve. The percentage content of P_2O_5 in the soil is then calculated according to the following formula:

$$X = \frac{100 \text{ x c x } 250 \text{ x } 50}{10 \text{ x } 25 \text{ x } 2 \text{ x } 1000} = 2{,}5 \text{ x c},$$

where X is the content of P_2O_5 in the soil, in %; c is the P_2O_5 concentration, in mg per 50 ml of analyzed solution, found on the graduated scale; 250 is the total volume of the initial soil extract (Solution A), in ml; 50 is the volume of solution prepared for analysis (Solution B), in ml; 10 is the weight of the soil sample, in g; 25 is the volume of Solution A used for analysis, in ml; 2 is the volume of Solution B used for photometry, in ml; and 1000 is the ratio coefficient between mg and g.

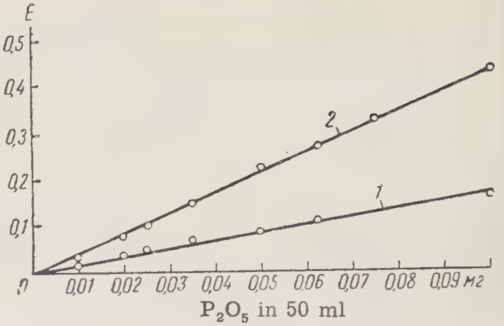

Fig. 1. - Set of calibration curves for phosphorus-molybdenum heteropolyacid solutions reduced with sulphite and the divalent iron salt.

1 - thickness of the liquid layer in the cell, d = 20 mm; 2 - d = 50 mm.

We made a comprative test of the suggested photometric method for determining the total content of phosphorus in the soil. A large number of samples from different kinds of soils were analyzed by this method and by Nissens' method. Some of the results are given in Table 1.

The data show that the differences between the results of the two methods are insignificant, ranging mostly from 0% to 0.01% P_2O_5. On the strength of our findings we recommend that the photometric method of determining total soil phosphorus with sulphite and divalent iron salts as the reducing agent by adopted for practical agricultural chemical studies.

We have also checked the possibility of using a different reducing agent in this method — hydrazine sulfate. One of the authors (5) had studied the reduction of the phosphorus-molybdenum heteropolycomplex with hydrazine sulfate previously. At present this reducing agent is being successfully used at the Ukrainian Scientific Research Institute of Farming for the large scale determination of available phosphorus in the soil (6).

The photometric method of total phosphorous determination using hydrazine sulfate consists essentially in the following operations: A 25-ml aliquot of a soil extract, obtained from the "wet" combustion of a soil sample, is treated as described earlier. Two milliliters of the filtrate (or any convenient number) is placed with an accurately graduated pipette in a 50 ml volumetric flask, and then are added 25-30 ml of distilled water, 5 ml of 2.5% solution of ammonium molybdate in 10 N sulfuric acid, and 2 ml of a 1% solution of hydrazine sulfate, and the liquid is brought up to volume with distilled water and shaken. At the same time, to a second flask used as a control, we add 5

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[3] 216g of iron-ammonium alum is dissolved in water with heating and 5 ml of concentrated hydrochloric acid is added. More water is added to make 1 liter.

Table 1

Results of comparative tests of the photometric method for determining total phosphorus in soil

Soil	Depth, cm	P_2O_5 content, % of soil weight		
		Nissens' method	Photometric method sulphite and iron salt	Deviation
Red earth	27—37	0,130	0,136	+0,006
		0,130	0,136	+0,006
Brown earth — red earth	0—10	0,221	0,225	+0,004
		0,211	0,219	+0,008
Red earth	0—10	0,085	0,075	—0,010
		0,084	0,075	—0,009
Red earth	0—10	0,105	0,110	+0,005
		0,105	0,110	+0,005
	50—60	0,075	0,073	—0,002
		0,076	0,074	—0,002
Gray podzolized	0—10	0,047	0,046	—0,001
		0,047	0,046	—0,001
Sod-weakly-podzolic	20—30	0,024	0,030	+0,006
		0,025	0,040	+0,015
Red earth	0—10	0,045	0,046	+0,001
		0,045	0,050	+0,005
Yellow earth	0—10	0,061	0,050	—0,011
		0,060	0,060	—
	32—42	0,025	0,025	—
		0,026	0,030	+0,004
	85—95	0,061	0,060	—0,001
		0,061	0,050	—0,011
Meadow podzolized	0—10	0,044	0,053	+0,009
		0,044	0,054	+0,010
Deep, low-humus, Coarse, clay loam chernozem	0—20	0,110	0,130	+0,020
		0,112	0,130	+0,018
	20—40	0,100	0,105	+0,005
		0,101	0,105	+0,004
	0—20	0,102	0,101	—0,001
		0,103	0,100	—0,003
	20—40	0,096	0,120	+0,024
		0,098	0,117	+0,019

Note: Comma represents decimal point.

nl of molybdate solution and 5 ml of the hydrazine sulfate solution. The liquid in the flask s brought up to volume with distilled water ind shaken. Both flasks are then put into a iot water bath for 20 minutes. During this ime, the blue phosphorus-molybdenum hetroolycomplex is formed in the first flask and the ree excess molybdenum is partially reduced o a yellow pentavalent molybdenum compound. n the flask containing the blank solution there s only a partial reduction of the molybdate to he yellow pentavalent molybdenum compound. Hence the blank solution assumes a yellow olor, and the solution being analyzed, a ellow-green. Then the flasks are cooled in old running water, brought up to volume with listilled water, shaken, and are then ready or photometry. The photometric procedure vas described earlier. The light-absorption alues of the solutions being analyzed remain oractically unchanged for a considerable length of time.

A sample set of calibration curves for phosphorus-molybdenum heteropolyacid solutions reduced by hydrazine sulfate is given in Figure 2.

It follows from the data of Figure 1 and Figure 2 that the reducing effect and photometric sensitivity are greater when hydrazine sulfate is used instead of sulphite and divalent iron salts, the sensitivity amounting to 0.001-0.002 mg P_2O_5 per 50 ml of analyzed liquid.[4]

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[4] K. Ye. Ginzburg (Pochvovedeniye, 1958, No. 2) came to the conclusion that the method of phosphorous determination using the blue molybdenum heteropolycomplex is rather insensitive, when hydrazine sulfate is used. The data in our set of curves (Fig. 2) and also the data from photometric studies cited by Ginzburg herself clearly show that this is an erroneous conclusion. Ginzburg's assertion that the

Footnote 4 continued on next page.

Table 2

Results of comparative tests of two modifications of the photometric method for determining total phosphorous content in soil

Soil	Depth, cm	P_2O_5 content, in % of soil weight, determined by photometric method, employing:		
		Sulphite and iron salt	Hydrazine sulfate	Deviation
Dark gray podzolized	0—20	0,075	0,074	—0,001
		0,076	0,074	—0,002
"	0—20	0,064	0,070	+0,006
		0,068	0,080	+0,012
Podzolized chernozem	0—20	0,093	0,100	+0,007
		0,104	0,100	—0,004
"	0—20	0,065	0,059	—0,006
		0,065	0,053	—0,012
Sod-moderately gleyed	0—18	0,071	0,069	—0,002
		0,072	0,069	—0,003
Sod-weakly podzolic	0—20	0,021	0,023	+0,002
		0,021	0,023	+0,002
Gray podzolized	0—20	0,048	0,050	+0,002
		0,048	0,050	+0,002
Sod-weakly podzolic	0—20	0,025	0,022	—0,003
		0,025	0,021	—0,004
"	27—37	0,031	0,022	—0,009
		0,031	0,022	—0,009
Sod-moderately-podzolic, gleyed, silty coarse clay loam	0—20	0,044	0,030	—0,014
		0,044	0,030	—0,014
Light-gray, podzolized, silty sandy loam	0—20	0,039	0,025	—0,014
		0,039	0,025	—0,014
Sod-moderately-podzolic clayey-sandy	0—20	0,018	0,016	—0,002
		0,020	0,016	—0,004
"	23—33	0,014	0,011	—0,003
		0,014	0,011	—0,003
Shallow, calcareous, silty coarse loam clay chernozem	0—20	0,085	0,073	—0,012
		0,085	0,071	—0,014
Meadow solonchak-like, silty clay loam	0—20	0,076	0,071	—0,005
		0,076	0,071	—0,005
Deep, low-humus, coarse clay loam chernozem	0—20	0,130	0,123	—0,007
		0,130	0,123	—0,007
"	20—40	0,105	0,097	—0,008
		0,105	0,099	—0,006
"	0—20	0,101	0,110	+0,009
		0,100	0,110	+0,010
"	20—40	0,120	0,115	—0,005
		0,117	0,115	—0,002

Note: Comma represents decimal point.

In both cases the solutions are subject to Beer's law, i.e., there is a direct proportion between the light absorption and phosphorus concentration.

The results of our comparative tests are

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method cannot be used for large-scale analysis is invalidated by the fact that this has been done very successfully at the Ukrainian Scientific Research Institute for Agriculture, as well as by other scientific and experimental organizations during current extensive soil investigations in the Ukraine.

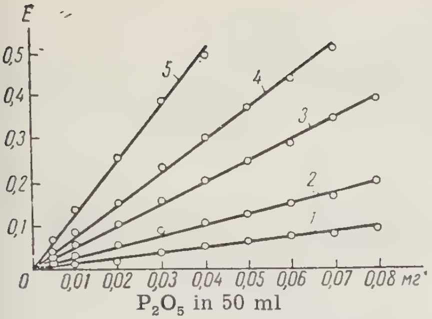

Fig. 2. - Set of calibration curves for phosphorus-molybdenum heteropolyacid solutions reduced with hydrazine sulfate.

1 - thickness of the liquid layer in the cell, d = 5 mm; 2 - d = 10 mm; 3 - d = 20 mm; 4 - d = 30 mm; 5 - d = 50 mm.

iven in Table 2.

These results permit us to recommend also hat the second variation of the photometric nethod (using hydrazine sulfate) should be sed to determine total phosphorous content n practical agricultural chemical soil analyses. 3oth variations of this method are being used t the Ukrainian Scientific Research Institute f Agricultural in the analysis of soil samples.

The use of sulphite and divalent iron salts s the reducing agent should be preferred when dealing with soils rich in iron (red earths, chestnut soils, and others).

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A RAPID METHOD OF DETERMINING ADSORBED SODIUM AND POTASSIUM IN CALCAREOUS SOILS

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Many years of laboratory experience show that current methods of determining adsorbed sodium and potassium in calcareous soils are rather cumbersome and often produce conflicting results when used concurrently.

Between 1949 and 1951 we developed a new method of determining adsorbed sodium and potassium in calcareous soils (1). Later this method was extensively checked on various samples of light and meadow sierozems from the Chuysk valley, Kirgiz SSR. We used this method to determine the solonetzization of loess-like materials and clays from certain deposits in Kirgizia.

To check the accuracy of this method, results were compared with those of the classical zinc-uranyl acetate method. Description of our method is taken from a paper published in 1951 but reflecting certain improvements and changes introduced since that time, as a result of practical experience.

Take about 5 g of soil and treat it in a porcelain dish with 0.2 N oxalic acid. The solution should be used in aliquots of about 100 ml each. Let the suspension in the disk stand for one or two hours, and then pour off the liquid through a funnel with filter. Repeat the operation until 500 ml of oxalic acid have been used. When the amount of adsorbed sodium and potassium is small, smaller soil samples can be used. These, in turn, will require corresponding smaller amounts of the displacing agent ($H_2C_2O_4$). Evaporate the acid extract in the porcelain dish, and then wash the dry residue from the porcelain dish with water into a platinum or nickel dish. Evaporate again to dryness in a water bath; then place the dish with the residue in a sant bath to remove the excess oxalic acid. Continue heating on the sand bath until there is no more evolution of white fumes. After driving off the excess $H_2C_2O_4$, place the dish and contents into a muffle or crucible furnace and ignite at 450°-500°C for 2-2.5 hours. This is enough time to convert all alkaline and alkaline-earth metal oxalates to carbonates and the iron and aluminum oxalates to oxides. In addition to iron and aluminum oxides, we also found in the ignited residue a small amount of magnesium oxide, but no calcium oxide. The MgO is the only compound present which easily dissolves in water (especially in cold water). Thus, in treating the ignited oxalate residue with water free of CO_2, magnesium oxide would partly dissolve with the carbonate salts of the alkali metals and be titrated with them. Entry of the magnesium oxide into the solution — treat the ignited residue of the oxalate extraction in the dish with a saturated solution of $Mg(OH)_2$ in the cold and filter it into a measuring flask (200-500 ml) through a funnel with a dense filter.[1] Check the extent of washing from the pH (Michaelis method). Filtration is discontinued when the pH of the filtrate corresponds to that of a saturated $Mg(OH)_2$ solution. The filtrate in the volumetric flask is brought up to the mark by adding $Mg(OH)_2$ solution. Pour 50 ml from the volumetric flask into a beaker and titrate with 0.02N sulfuric acid and a methyl orange indicator until a pale pink color appears. At the same time an aliquot of the saturated $Mg(OH)_2$ solution is titrated with the same acid. The amount of sodium and potassium contained in the filtrate sample is indicated by the difference in the amounts of acid used to titrate the filtrate obtained after treating the ignited residue with saturated Mg $(OH)_2$ and the saturated $Mg(OH)_2$ solution itself. On the basis of this the content of sodium and potassium can be converted to meq/100 g of soil.

We compared the results obtained by our method with those by the methods of Gedroyts and Puri. The results obtained by the oxalic acid method in parallel determinations (titrations) occupy a middle position between the results produced by the other two. The same was true when all three methods were used in experiments with soils containing known amounts of adsorbed sodium, potassium, and magnesium (1). Since then our method has been repeatedly checked in the laboratories of the Chemical Institute, Academy of Sciences of the Kirgiz SSR and of the Land Development Administration of the Ministry of Agriculture of the Kirgiz SSR. Various soils, including loess-like clay loam, were used for this purpose.

The comparative data obtained by the three methods are given in Tables 1, 2, and 3. Table1

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[1] The saturated $Mg(OH)_2$ solution is prepared from chemically pure MgO and distilled water purified of CO_2 by precipitation and filtration.

Table 1

Content of absorbed sodium and potassium in samples of different soils from "Tamchi" sovkhoz expressed in meq/100 g of soil[a]

Test No.	Profile No.	Soil	Depth, cm	$H_2C_2O_4$ method		Gedroyts method, volumetric variant
				Volumetric variant	Zinc-uranyl acetate	
6	18	Light sierozem	0—20	10,23	10,95	10,90
3	2	Northern light sierozem	19—23	3,7	2,8	4,0
2	1	"	40—50	1,9	2,1	1,97
7	118	"	109—119	2,18	2,3	2,0
1	18	Light sierozem	2—12	2,4	2,4	—
8	32	Northern light sierozem	49—54	4,1	4,7	3,5
10	18	"	50—60	2,9	2,6	2,8

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[a] The data was obtained by A. Ya. Lukonin in the Soil Laboratory, Land Development Administration, Ministry of Agriculture, Kirgiz SSR.

Note: Comma represents decimal point.

Table 2

Content of adsorbed sodium and potassium in meadow sierozems of Sokuluksk main station (profile 26), meq/100 g of soil

Depth, cm	$H_2C_2O_4$ method		Gedroyts method, using zinc-uranyl acetate
	Volumetric variant	Zinc-uranyl acetate	
0—15	2,34	2,51	2,54
30—40	2,73	2,93	3,30
65—75	4,71	4,31	3,70
105—115	6,55	5,52	5,55
150—160	12,52	11,07	10,94

Note: Comma represents decimal point.

Table 3

Content of adsorbed sodium and potassium in loess-like materials and clays of certain deposits in Kirgizia, expressed in meq/100 g of dry clay

Deposit	Gedroyts method (volumetric varient)	Oxalic acid method (volumetric varient)
Kara-Su	3,92	3,33
Tokmak	2,40	2,84
Osh	3,72	3,63
Kirovka	3,54	3,35
Minkraska	3,95	3,65
Kol'tsovsk kaolin	6,90	4,79
Leninpol'	3,10	1,49
Kainda	6,50	4,1

Note: Comma represents decimal point.

shows that the oxalic acid method deviates from the Gedroyts method by not more than ±10%. Only in the case of an abnormally high combined total of sodium and potassium, Sample No. 8, was this discrepancy more substantial. As we established, the Gedroyts method usually tends to produce higher values (2).

Table 2 shows comparative results by the oxalic acid method, when used for large-scale analyses. As compared to the standard zinc-uranyl acetate method, the range of deviations was ±<9%. Table 2 also provides a comparative record of the amounts of sodium adsorbed when the soil was treated with oxalic acid and when the Gedroyts method was used. In both cases these amounts were determined by zinc-uranyl acetate. If the amount of sodium shown by the Gedroyts method is taken as 100%, then in most cases the relatiae error does not exceed ±1.2%.

Table 3 shows that the two methods produced very similar results in loess-like materials and clays of Kirgizia.

On the basis of these facts, we recommend that this rapid and readily available oxalic acid method be employed by soil research laboratories.

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REVIEW

THE TEACHING OF SOIL SCIENCE IN FORESTRY COLLEGES AND THE TEXTBOOK OF PROFESSOR A. A. RODE

S. V. ZONN, V. N. SMIRNOV and A. A. MOLCHANOV

For proper evaluation, A. A. Rode's major work, entitled Soil Science, should be considered from several viewpoints. First, it should be determined whether, as a textbook, it provides students with a comprehensive presentation of the subject. Secondly, the book should be judged on its usefulness as a practical scientific aid for soil scientists, silviculturists and other specialists who need to increase their professional knowledge. Thirdly, it would be important to see how fully this book covers modern progress in soil science and their practical application in silviculture.

In our opinion, before considering these three aspects, we should take a look at the present situation in the teaching of forest soil science courses and problems involved. Rode's book has a direct bearing on these problems.

At present forestry college curricula allocate 178 hours to the teaching of soil science, including the principles of geology. Soil science proper receives about 130-140 hours of this time. This is barely enough for a somewhat sketchy presentation of the principles of soil science and some aspects of the soil-forest relationship.

This is presumably because the problems of soil-forest relationships and interaction are included in another course, "silviculture." However, it should be noted that even in the latest silvicultural textbooks these problems are not presented in the light of modern theoretical and practical achievements. As a result, there is a tendency to underestimate the effects of soil conditions on forest growth and productivity in solving practical silvicultural problems. It would be sufficient to point out that some current silvicultural books assert that "the forest is the cause and result of the podzolization." Such ideas on soil-forest interaction processes are, on our opinion, directly related to the insufficient attention given to this subject in colleges. Another contributing factor here is the extremely rapid pace of development and specialization in this field of science. So much new data and material have been accumulated that it is practically impossible to summarize them within the limits of silvicultural courses.

We think that it is high time, therefore, to create a separate course encompassing scientific knowledge pertaining to soil-forest relations and interaction. It should be taught to students who have completed a course in soil science principles. Actually, this new course should be a presentation of forest soil science based on general soil science, dendrology, climatology, microbiology, plant physiology and other related scientific subjects.

Owing to successful studies of soil-forest inter-relation problems by our scientists during the last two or three decades, Soviet forest soil science occupies a leading position in the world. Our principles of studying these problems have been adopted and developed in many countries of Europe, Asia, and America. In our colleges, therefore, this branch of soil science must be raised to an appropriately high level. If it should be difficult at this time to introduce a separate course, then we should think in terms of increasing the number of hours allocated to the soil science course, so that soil-forest relations could be included. Except for a lecture series by G. N. Vysotskiy entitled "On forest matters" and designed for advanced soil-science students, there have been no attempts made in our country to initiate such a broadened course.

We cannot help but notice that universities and technical institutes in East and West Germany have in their forestry schools separate departments of forest soil science and forest ecology. One of their tasks is to teach courses in soil science, forest soil science, and forest ecology (soil science is a prerequisite), as well as to conduct corresponding research. Already the second edition of S. A. Wilde's monograph Forest Soils has been published in the USA. This book represents an interesting attempt to summarize a great amount of material, obtained primarily in Western Europe, and its contents amount to a course in forest soil science. It would be easier to consider properly and evaluate A. A. Rode's work, Soil Science in the light of these facts.

The book is based on the latest data on soil science and thus provides the reader with an opportunity to learn more about modern scientific achievements and to approach debatable and still unsolved problems critically. The book emphasizes forestry by discussing not only soil science principles, but also special problems of forest soil science. Thus, the chapter on soil organic matter includes a special review of forest soil organic matter. By the same token, the chapter on soil erosion gives a considerable amount of attention to the role played by forests in controlling soil erosion. Special chapters are devoted to the hydrological effects of the forest and the interchange of mineral substances between soil and vegetation (primarily forest vegetation). Soil fertility is discussed mostly in terms of its relation to trees found in our forests. When describing the main soil groups, the author makes at least brief reference to their forest-growing properties.

In this way the author succeeds in combining general soil science with special problems of forest soil science. It is worth noting that the chapters dealing with general aspects of soil science are very comprehensive and so arranged as to prepose the reader gradually to cope with more complex processes of soil formation, development of different soil groups and their geographic distribution. The author made the right decision in first providing only general ideas on specific soil features and properties and later developing and discussing them in more detail. Thus, for instance, on page 56 Rode gives a brief idea of the soil profile. He then proceeds to discuss morphological features and on page 70 returns once again to soil profile, but this time in much more detail. Finally, he returns to this topic again in discussing the soil formation process. He briefly reminds the reader that the solum is made up of genetic horizons.

In our opinion, this is a good teaching method. It makes the reader seek a deeper understanding of specific problems and return to them when his general knowledge of the subject has been increased.

Repetition is an effective teaching method, too. Rather than repeat definitions or explanations, the author often refers the reader to earlier chapters of the book. And by going over the material seen earlier, the reader gains a better understanding of the whole subject.

Thus, it is quite clear that Rode's book Soil Science not only contains up-to-date material on the main theoretical and practical achievements of soil science, but also meets the requirements of a comprehensive textbook.

All of this has been already said in a more detailed review by N. L. Blagovidov.[1] the reason we decided to do it again, is another, and more recent, review of this book by S. A. Zolotarev.[2] Unlike Blagovidov, Zolotarev was favorably impressed by hardly anything in Rode's work. In his opinion, Rode's attempt to produce a useful textbook was a complete failure. However, Zolotarev himself fails to specify even one substantial defect of this book. In fact, his evaluation of this work written by a highly-qualified specialist cannot be called either objective or unbiased. Witness, for instance, the following remarks from his review: "It is obvious that the sentence cited lacks logic and clarity," "extremely inaccurate," "poor thinking," "illogical combination of conflicting ideas," "personal fabrications," "failed to do the job of the textbook-writing."

Zolotorev believes that the textbook contains too many repetitions and that "a considerable part of the text is made up of such expressions as: 'as we already know', etc." It is quite obvious that Zolotorev is simply suffering from hyperbolism. Should his assertion about the abundance of parenthetic phrases be true, there would not be much point in producing such a meaningless textbook and, subsequently, not much interest on the part of any publisher to publish it. As we have already demonstrated, what the book actually has are not merely repetitions, but rather devices for a gradual development of one or another concept in accordance with progressive teaching methods.

Such are, in essence, the main general defects of the book, as alleged by Zolotarev.

According to him, the main methodological defect of the book is the absence of a definition of the basic principle of modern soil science, namely: "... soil formation is by its nature a biological process and soil represents a medium in which a two-way process of transformation — the synthesis and decomposition of organic matter — takes place." Then the proceeds to consider five pairs of opposite phenomena, pointed out by Rode, and reproaches the author for not having identified the main pair. Disregarding Zolotarev's ridiculous grammatical construction in the sentence quoted, let us just say that it would be quite inadequate and confusing simply to declare that soil formation is a biological process, without using my supporting factual evidence. It would be equally wrong to declare that soil formation is determined by the synthesis and decomposition of organic matter alone, while ignoring all other factors.

Let us see what Rode has to say about this. On pages 292-293 he wrote that among the soil forming factors are flora and faunna, parent materials, etc. And also that: "Vegetation — which causes the biological migration and accumulation of ash materials, creates organic matter, and brings about its decomposition (micro-organisms) — is the main force in the soil formation process." On pages 334-484 Rode again emphasizes the importance of the biological factor. It is rather strange that Zolotarev did not notice this and, instead, managed to see a contradiction in Rode's belief that the soil formation process is affected by all factors which Dokuchayev called "soil-forming factors." Zolotarev also finds a contradiction in Rode's remarks about the extreme importance of climate in the soil formation process. It seems that, according to him, Rode should have put vegetation first in all instances. This means that Zolotarev cannot see the difference between soil formation and geographic soil distribution. Hardly anybody utside himself would deny that geographic soil istribution depends first of all on climate and elief, while the other factors play a subordinte role. Vegetation itself depends on climate, hile relief has a decisive effect on the redisribution of heat and moisture, which are imortant conditions in soil distribution.

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[1] Pochvovedeniye, 1957, No. 8.

[2] S.A. Zolotarev, "An unsuccessful manual on Soil Science for forestry colleges." Nauchn. dokl. vysshey shkoly, Biologicheskiye nauki, No. 1, 1959.

Other remarks by Zolotarev are of the same ype. It is very regrettable, for instance, hat he was not able to comprehend Dokuchayev's efinition of soil given by Rode on page 9 of his ook. Dokuchayev was attaching a special imortance to the effects of vegetation on soil deelopment, when he wrote that the term "soil" hould refer to the exposed horizons or the adacent rock strata as modified by the interaction f "water, air, and various organisms — livng and dead." Somehow or other Zolotarev nterpreted this to mean that Dokuchayev did ot recognize the leading role played by oranisms in the soil formation process. Such revision of Dokuchayev's concepts, disouraging the biological approach to soil scince, deserves to be refuted.

This would have been sufficient for a critiue of Zolotarev's arguments against the textook had he not made it his review certain ersonal charges against Rode, accusing the atter of being incompetent. Let us consider ust one of these changes. In his book Rode tated that the main reasons for weathering f minerals are the internal properties of inerals, in particular, their tendency to ncrease in volume or, as it were, to loosen heir framework. He then explained that his tendency alone is not enough and that ertain outside forces, contained in surroundng natural substances, are needed. All this s stated in plain language and leaves no room or any misinterpretation. Yet, Zolotarev anaged to see here some sort of contradicion.

Others of Zolotarev's remarks are very imilar and the apparent reason for them seems o be his ignorance of modern achievements in oil science, geology and mineralogy.

We have pointed out the merits of A. A. Rode's work as a textbook for forestry college students. In conclusion, we would like to evaluate it also from the two other viewpoints mentioned at the beginning of this review.

Is this textbook useful for soil scientists and specialists in related fields? The answer to this question is an unconditional "yes," because Rode's work summarizes the latest data on the hydrological importance of forest vegetation and on other problems. Otherwise these data can be found only by looking through many different original sources.

Each chapter of the book contains an extensive bibliographical list for the benefit of readers who might like to get more information concerning specific topics. Now for the last question "Does the book fully cover modern achievements in general and forest soil science?" Here we must admit that the book falls short of the mark. While soil science principles are presented at the modern level of knowledge, many problems of forest soil science, excepting those that pertain to the hydrological role of the forest, do not receive enough attention.

But this fact should not be blamed on the author, who had to comply with the program adopted by the USSR Ministry for Higher Education and who was also limited to the agreed size of the written work.

We would only like to express our hope that the author should be able to include more material of this nature in the second edition of his otherwise very successful work. And that it is a very successful work is quite evident despite Zolotarev's review, which was, to say the least, unsuccessful. The following facts speak for themselves: The textbook is being used not only by forestry colleges but has also been recommended by a number of universities (in particular, by the Geography Department of Moscow State University). It has been translated into Chinese and enjoys popularity in other countries.

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